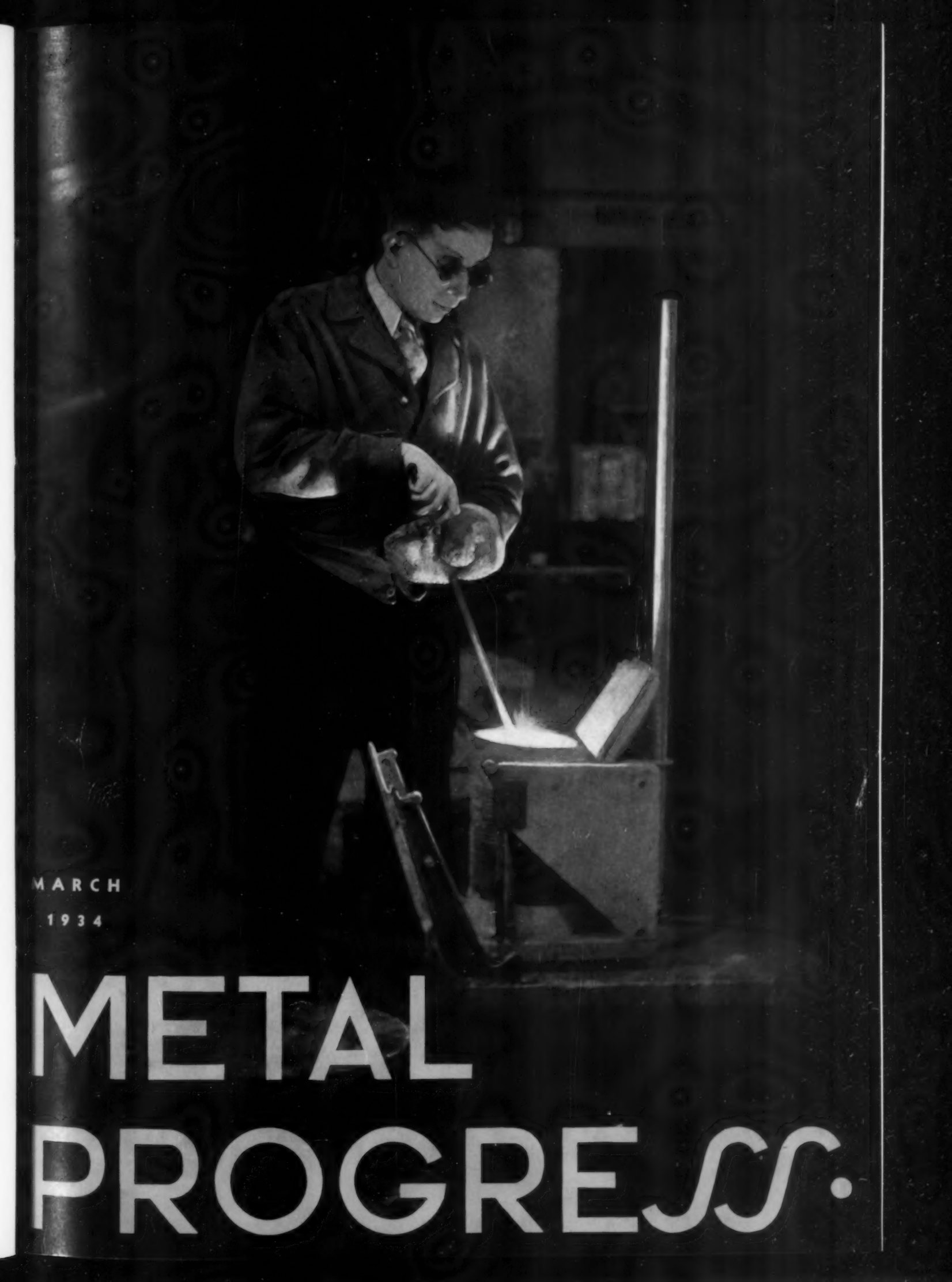

MARCH
1934

METAL PROGRESS

A COMPLETE REPORT BY UNIVERSITY OF MICHIGAN

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WILKINSBURG STATION, PITTSBURGH, PA.

March, 1934
Vol. 25, No. 3

METAL PROGRESS

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The cover is from a fine action photograph taken in the Detroit Research Laboratory of the Climax Molybdenum Company by the late J. KentSmith.

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Wesley P. Sykes ("Bill" to you) has been studying tungsten and other refractory metals for incandescent lamps ever since graduation, and the method of production—by powders—has interesting possibilities for commoner metals. A recent achievement of our hero is the development of new tool materials, hardenable alloys of tungsten, cobalt and iron.

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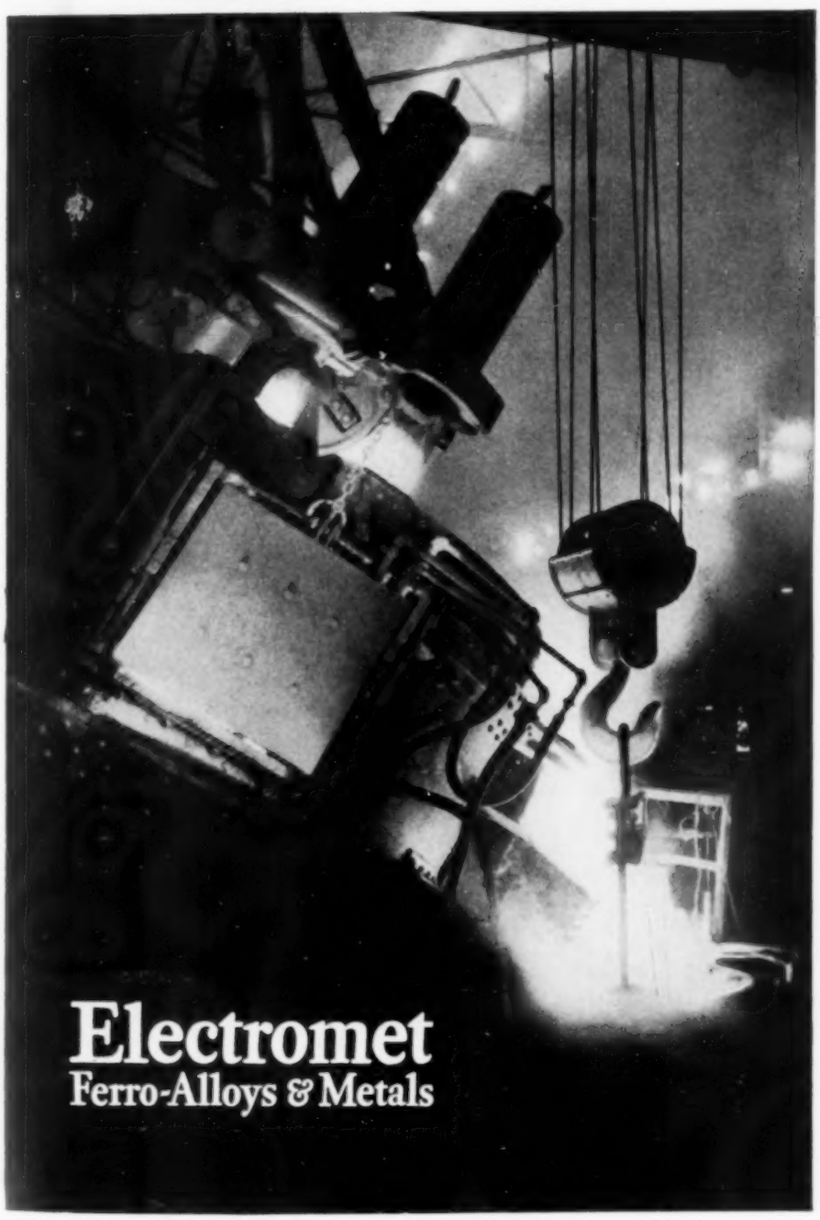


Electromet
Ferro-Alloys & Metals

CHROMIUM
High Carbon Ferrochrome (maximum 6% carbon)
Low-Carbon Ferrochrome (in grades, maximum 0.06% to maximum 2.00% carbon)
Chromium Metal
Chromium-Copper
Miscellaneous Chromium Alloys

SILICON
Ferrosilicon 15% Ferrosilicon 50%
Ferrosilicon 75%
Ferrosilicon 80 to 85%
Ferrosilicon 90 to 95%
Refined Silicon (minimum 97% Silicon)
Calcium Silicon
Calcium-Aluminum-Silicon
Calcium-Manganese-Silicon
Silicon-Copper
Miscellaneous Silicon Alloys

TUNGSTEN

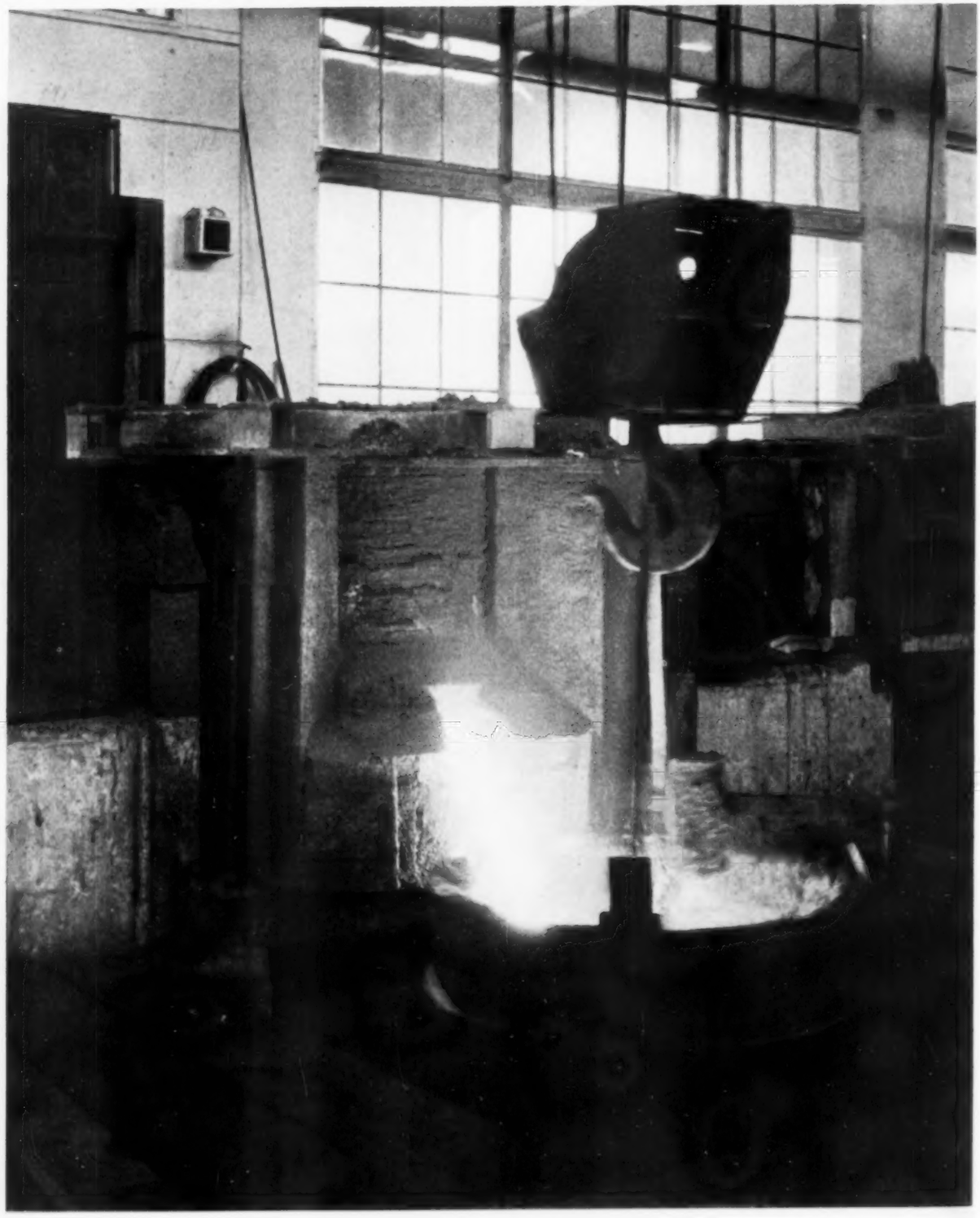
MANGANESE
Standard Ferromanganese 78 to 82%
Low-Carbon Ferromanganese
Medium-Carbon Ferromanganese
Manganese Metal
Manganese-Copper
Miscellaneous Manganese Alloys

SILICO-MANGANESE
All grades including Silico-Spiegel

VANADIUM
All Grades

ZIRCONIUM
Aluminum-Zirconium
35 to 40% Zirconium
12 to 15% Zirconium
Zirconium-Manganese-Silicon

BRIQUETS
Chrome Briquets Silicon Briquets
Manganese Briquets



Stationary Induction Furnace
Tapping 3000-lb. Heat

by Prof. C. A. Adams
Consulting Engineer
Harvard University

J. C. Hodge
Chief Metallurgist
Babcock & Wilcox Co.

M. H. MacKusick
Electrical Engineer
Babcock & Wilcox Co.

REFINING ALLOY STEEL

in high frequency furnaces

THREE MOST IMPORTANT FEATURES of the induction furnace for steel melting are as given just below, and its field has been largely governed by these characteristics:

A — In common with the electric arc furnace, the melt is free from contamination by the products of combustion of fuels. It possesses a further advantage over the arc furnace in being free from any possibility of carbon pick-up. This has resulted in its application to the production of alloys such as low carbon stainless irons and magnetic alloys. Considerable tonnage of the former is produced by remelting scrap of corresponding analysis, which could not be conveniently reclaimed by any other melting process.

B — Electromagnetic stirring of the molten bath results in a homogeneous melt, and it is impossible to conceive of any segregation of alloys for more than a short period of time after the alloy additions.

C — The high temperature obtainable fits it to refractory melts such as tungsten, molybdenum, cobalt, and chromium and alloys thereof, and to the production of tool steels, high nickel alloys, and corrosion and heat resisting iron-chromium or iron-nickel-chromium alloys.

While other characteristics are subsidiary to the above three, the rapidity of melting and the great flexibility of an induction furnace installation in changing from heat to heat of varying analyses is a considerable advantage in producing various alloys of the above types, which are melted in comparatively small sized heats.

We may now consider in greater detail the metallurgical aspects of the most characteristic feature of induction furnace melting; namely,

Turbulence of the Bath

When a charge of cold metal first receives power, certain favorably situated or shaped pieces will melt first. Owing to the fact that this melted material in the bottom of the crucible intercepts more flux than the small unmelted pieces, it receives more power than any similar quantity of the unmelted scrap, and it rapidly becomes superheated and a certain amount may be oxidized. These effects may be limited and serious erosion of refractory lining prevented by proper adjustment of the rate of heating (power input). Furthermore, in starting with a cold charge it is desirable to sprinkle the hot but unmelted pieces of metal with slag-forming materials to prevent undue oxidation. (Some slight danger is involved of the unmelted material bridging the crucible by the use of slag

during the melt-down period.) The local overheating of the first liquid metal may also be avoided by leaving sufficient molten metal from the previous heat, although this can only be done where the chemistries of the successive heats are not in conflict.

(It is appropriate at this time to mention that some trouble may be encountered due to contamination of a melt from the slight skull left in the furnace from the previous heat. This is, of course, common to all furnaces but is accentuated in a small sized melt. In changing to a radically different analysis, it is therefore sometimes necessary to melt a wash heat of low carbon iron.)

Agitation of the completely melted bath must not be so great that the metal boils up through the slag covering, with resultant exposure to the air. This effect is readily apparent in comparative analyses of two heats of 18-8 chromium-nickel stainless alloy. One was melted by 60-cycle power, which raises the center of the bath above the slag; it contained 0.117% nitrogen. The other was melted by high frequency current (960 cycles) with the surface fully protected, and it contained 0.030% nitrogen. Excessive turbulence should therefore be avoided, particularly with those metals which readily absorb oxygen and nitrogen — as does chromium. Fortunately, the movement of the bath can be readily controlled within limits by regulating the power to a furnace of a given size at a given frequency.

A paper, "High Frequency Induction Furnaces" was prepared by the authors for the American Institute of Electrical Engineers. Its first draft contained a discussion of the electrical characteristics of the furnace and its power units, based on a simplified mathematical treatment as well as some discussion of the metallurgical operations. The latter portion was much abbreviated when presented to the Electrical Engineers, and this portion is now given to an audience more in keeping with the subject matter.

Deoxidation Under Acid Slag

The possibility of refining steels under a slag in the induction furnace was early recognized and many papers have been published showing the rapid removal of carbon, phosphorus, and sulphur under appropriate slags. Since elimination of these metalloids is performed readily in open-hearth, bessemer, and electric arc furnace practice, we believe it properly has no place in induction furnace melting. Elimination of oxygen is of much greater importance, and presents greater although not unsurmountable difficulties.

Refining a melt under a slag in the induction furnace is aided by the agitation of the metal and is restricted by the quiescence and low temperature of the slag. In an arc furnace the slag is at a higher temperature than the steel, is liquid, and sometimes violently agitated. The slag covering an induction furnace melt is, on the other hand, colder than the metal and may in some cases be too cool for satisfactory reactions to take place. It has been suggested that the slag might be heated by auxiliary means, such as an arc or a burner. This expedient is unnecessary if slags of low melting point are judiciously formulated, which will remain liquid by transfer of the heat from the surface of the metal.

If its melting point is below that of the metal, the slag layer at the interface is at the same temperature as the metal bath and therefore molten. Reactions between this slag layer and the bath proceed and are aided by the agitation of the melt, which also tends to renew continually the molten slag layer above the surface with fresh slag. Equilibrium between slag and melt may therefore be attained fairly rapidly, regardless of the thickness of the molten slag layer above the metal surface.

Choice of slag will depend on the nature of the lining and of the alloy being melted. At the present time acid linings and slags are used almost entirely at the plant of the Babcock & Wilcox Co. Inasmuch as the refining reaction is largely one of oxide reduction, slags possessing a high fluxing power for iron oxide (or chromium oxide in the case of the corrosion and heat resisting alloys) are used. Ground

sodium silicate with a soda-silica ratio of 1 : 3.22 is giving good results. An outer ring of silica is used with the sodium silicate to prevent undue attack on the ganister lining by the sodium silicate with its high fluxing power. Other slags may be made by mixing lime and ganister fines in the proportion of 70% lime and 30% silica for basic magnesite linings, and in the proportion of 60% silica and 40% lime for acid ganister lined furnaces. Small additions of fluorspar may be made to the slag.

Deoxidation of the metal in the furnace is produced through the slag; that is, the finely ground deoxidizer is intimately mixed with the ground slag-forming materials. This procedure is quite effective, as is proven by the control analysis of a 1000-lb. heat (*A* of the table) of 18-8 made in a basic magnesite lined high frequency furnace. The charge consisted of tubular scrap of the same alloy.

All slags in heat *A* were made up by a mixture of 70% lime and 30% silica, the total weight of the mixture being 30 lb. To this mixture 4 lb. of calcium silicide was added and intimately mixed. (Other deoxidizers have also been used successfully. It is possible to add manganese and silicon to the melt in this manner, although ferromanganese must be added directly to an acid melt.)

The first slag was skimmed at 12:00 noon. It is the melt-down slag, produced by the scale originally present on the scrap, by the oxidation of the scrap during the melting period, and by the lime-silica mixture sprinkled on the unmelted scrap during melt down. It contains a large amount of oxides and it is very dark colored. After it was skimmed, 6 lb. of the mixture was added for a second slag, and so on. The second slag possesses a much lower oxide content and is thin and green in color, and was skimmed at 12:35. The oxide content of the third slag, skimmed at 1:00 p. m., is sufficiently small to produce a white slag which powders on cooling in the same manner as normal basic arc furnace slag. Examination of the analyses for heat *A* shows that the iron, chromium, and manganese oxides decrease for each successive slag until reduced to a negligible amount. At 1:40 the fifth slag was skimmed and the heat poured.

Basic induction furnace slags have been produced with even lower iron oxide contents; an analysis of a final refining slag of this type (line 6 of the table) is compared with line 7, which is the analysis of a typical slag of a basic arc furnace on a low carbon stainless heat. The analyses of both slags are approximately the same and refinement of the metals in both furnaces should proceed to the same degree, provided time for establishment of equilibrium between slag and metal is given.

Acid slags may be similarly worked. The analyses of four successive slags from a 1500-lb. heat of 18-8 in a ganister-lined furnace are presented as lines 8 to 11 in the table. The greater oxidizing ability of the acid furnace is shown by the chromium and manganese contents, which increase with each succeeding slag; on the other hand, FeO is constantly reduced. Other typical acid slags are No. 12 to 14.

Analyses of the slags from Heat *A* show that the magnesia is continually increasing, a

Slags From Induction Furnace Heats of 18% Cr, 8% Ni Alloy

Line		SiO_2	CaO	FeO	Cr_2O_3	MnO	MgO
		Basic Lining, Heat A					
1	Melt down	33.60	42.24	16.01	6.45	1.60	0.52
2	Second slag	38.32	49.73	4.90	2.84	1.16	2.90
3	Third slag	21.32	65.74	2.20	0.82	0.57	7.20
4	Fourth slag	23.86	63.50	2.01	0.60	0.24	9.40
5	Final slag	24.72	59.30	1.70	0.30	0.14	12.60
		Basic Lining, Heat B					
6	Final slag	28.30	57.68	0.28	0.13	0.32	10.97
		Basic Lining in Arc Furnace, Heat X					
7	Final slag	31.00	56.00	(Note a)	0.80	0.50	3.00
		Acid Lining, Heat C					
8	Second slag	58.15	32.88	2.20	1.30	1.08	0.46
9	Third slag	54.62	40.50	1.82	2.39	0.59	0.44
10	Fourth slag	60.04	32.14	0.87	2.39	2.11	0.72
11	Final slag	58.01	29.04	0.30	5.10	5.72	1.02
		Final Slags in Other Acid Heats					
12	Heat D	49.20	15.06	5.86	18.68	10.44	0.70
13	Heat E	49.00	9.86	3.15	25.86	11.07	0.89
14	Heat F	59.20	22.64	3.63	0.61	12.77	0.92

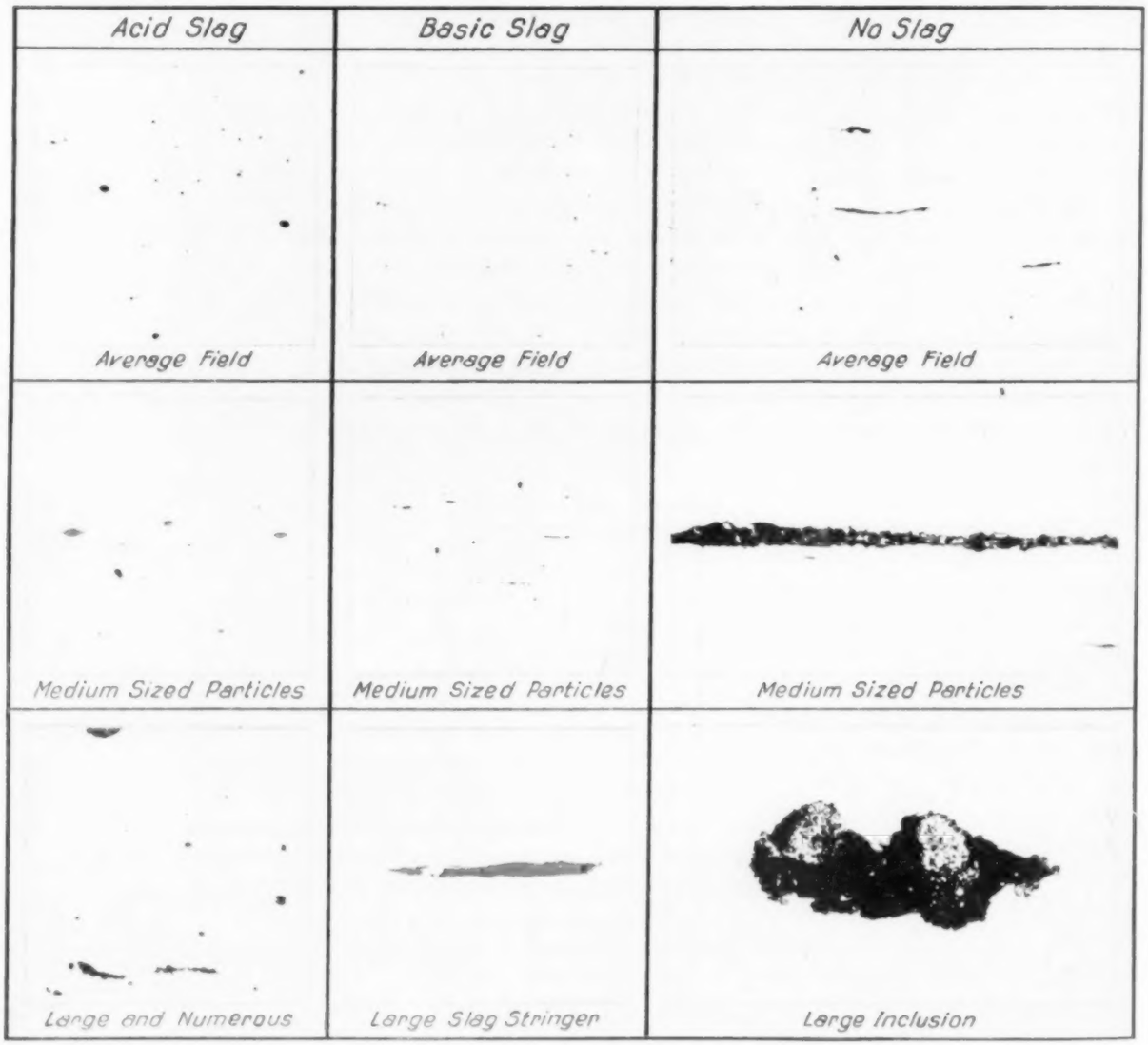
Note a: No FeO; 4% Al_2O_3, 4% fluorine

result of erosion and fluxing of the magnesite lining at the slag line.

Cleanliness of Induction Steels

Rapid agitation of the metal, which hastens the reactions between metal and slag and thus speeds the refining, also hinders the production of steel with low contents of solid non-metallic inclusions (sonims). Slag particles are drawn into the melt and it may be reasonably expected that the particle size of the entrained slag is small and kept small by the rapid movement of the bath. Since particle size is the most important factor in the elimination of inclusions the steel will show a high inclusion count under the microscope, somewhat greater than electric arc furnace steels, unless coalescence occurs.

An inclusion count of several induction furnace and arc furnace steels of the same analysis shows, respectively, values of 0.13 to 0.55% of the area occupied by inclusions in the induction steel, and 0.087 to 0.13% of the area occupied by inclusions in the arc furnace steels.



Micros at 100 Diameters of Unetched 3-In. Forged Bars of 18% Chromium, 8% Nickel Steel Melted in Induction Furnaces. Acid slag particles do not coalesce very rapidly, but even so the steels made under them are far cleaner than those melted without a cover

However, clean steels may be produced in induction furnaces, as is proved by the inclusion counts on the low side of the range given above, and by the micros on page 18.

To aid in the coalescence of the small slag particles, and thus in their more rapid and complete elimination, a period with minimum movement of the bath should precede pouring. A gentle agitation of the bath is preferable to complete quiescence; furthermore, with power shut completely off, the melt rapidly loses heat.

It should also be appreciated that the rate of coalescence depends upon the chemistry of the slags. The governing factors in the coalescence of inclusions in open-hearth steels have been described by Herty and his co-workers, and a complete study of this problem as applied to induction furnace melting would be extremely valuable. Several different types of inclusions found in induction furnace melts of 18% chromium, 8% nickel iron alloys are presented in the accompanying photomicrographs. Some evidence shows that the slag particles of basic furnace induction heats are generally larger than the glassy ones in acid heats.

It is somewhat unfair to draw final conclusions as to the cleanliness of induction furnace steel as compared to steels of other steel making processes, as our experience has been limited to furnaces of 3000 lb. maximum capacity. The future trend will undoubtedly be to larger units; one steel plant is using at present a 4-ton furnace and it is expected that these larger units will greatly simplify the problems arising from the rapid agitation of the molten bath of small induction furnaces.

No difficulty is experienced in melting any analysis of steel in this type of furnace. No excessive loss of the usual alloying elements occurs with the exception of the readily oxidizable elements such as silicon, manganese, and aluminum, which are only present in small quantities in the usual commercial steels and the loss of which can be readily compensated for by small additions previous to tapping. The normal chromium loss in melting 18-8 either from scrap or virgin materials is only 0.5% — that is, 18% chromium charged, 17.5% in final analysis (if no further chromium is added).

Acid or basic lined furnaces may be used with the normal metallurgical advantages and disadvantages inherent in each. The type of lining will be largely governed by the type of metal melted and by the affinities of the elements of the melt for oxygen as related to the stability of the magnesite or silica of the basic or acid linings respectively. Alloys containing appreciable quantities of aluminum, vanadium, manganese, and other elements of high affinity for oxygen are preferably melted in magnesite linings to prevent undue loss, as would occur in acid lined furnaces.

Production of Specific Analyses

A very good demonstration of the ability to produce alloys to a desired analysis is afforded by analyses of two heats of 18% chromium, 8% nickel — one a low carbon and the other a medium carbon alloy. Each heat weighed 4500 lb., having been made by simultaneously melting in a 3000-lb. and a 1500-lb. capacity furnace, and then mixing in a large ladle. The desired analysis had a narrower range for the individual elements than normally specified for this type of alloy, yet in the actual analysis the value obtained for each element as shown in the table was approximately at the mean of the specified range!

An example of the ability to produce, in an induction furnace, heat after heat of a given analysis within a limited *(Cont. on page 58)*

Performance on Two Heats of 18-8

	Carbon	Manganese	Silicon	Chromium	Nickel
Desired analysis (low carbon)	0.07 max.	0.30 to 0.60	0.30 to 0.70	17.75 to 19.0	9.25 to 10.0
Mean of desired range		0.45	0.50	18.37	9.62
Actual analysis	0.067	0.50	0.65	18.21	9.56
Desired analysis (medium carbon)	0.15 max.	0.30 to 0.60	0.30 to 0.70	17.75 to 19.0	9.25 to 10.0
Mean of desired range		0.45	0.50	18.37	9.62
Actual analysis	0.125	0.47	0.58	18.50	9.67

by Frederick C. A. H. Lantsberry
President, William Jessop & Sons, Inc.
New York

QUALITY OR "BODY"

of carbon tool steel, crucible melted

PRIOR TO THE INTRODUCTION OF HIGH speed steels at the end of the 19th century, practically all metal was cut and formed by tools of straight carbon steels, crucible melted. With the advent of high alloy tool steels, however, interest in the humble carbon steel waned to a degree which led certain enthusiasts to predict an early demise of the product which has played so large a part in the development of our civilization. But, like the report of Mark Twain's death, the disappearance of carbon tool steels was "grossly exaggerated"!

Statistics show that in 1929, the value of high speed tools produced in the United States amounted to $30,000,000 as against $13,000,000 worth of carbon tools. Since these statistics refer only to machine tool accessories and small cutting tools, and do not take into account tools made within a plant's own tool room for production purposes rather than for sale, the importance of the role played by carbon tool steels cannot be exaggerated. This survival of the old-fashioned material clearly proves a remarkable intrinsic merit, for research work and commercial promotion have been lavished on newer tool materials to almost the entire exclusion of crucible carbon steel.

As a matter of fact, accurate scientific knowledge is sadly needed, for there is probably no branch of industry more strongly affected by psychic disturbances than the production of tools. Dollars are spent for labor on a piece of steel costing as many cents, and a few cents more are then spent on the hardening operation. If, for any reason, the tool fails, an unreasoning state of panic generally ensues from which emergence is by the way of changing the steel. Many alloy steels have obtained their entry through this door into places where carbon steels are really better adapted (and this is also true of many recently made applications of alloy steels to machinery parts).

Aside from the more elusive factors of quality to be discussed later, the case for carbon steels may frequently rest on the circumstances that they are easier to machine and form into shape. There are many purposes in which they actually give better results on sheer merit and still more purposes in which short runs give them an economic advantage over the more costly alloy steels.

During recent years there have appeared quite a number of papers in METAL PROGRESS and *Transactions* of the A. S. S. T. pointing to a general revival of interest in carbon steel. Some of these papers have opened up new methods of investigation and have thrown much light on their behavior under specific conditions.

It is not surprising that the study of carbon steels should have been neglected during the period of development of alloy steels, because interest in a *new* development is the essence of progress. Nor can it be denied that the introduction of alloy tool steels marked a technological advance of almost indescribable importance. Nevertheless, one very important factor which also applies to carbon steels is frequently overlooked and that is the development of our knowledge of heat treatment.

Thirty years ago, when high speed steel was first introduced, our knowledge of the principles underlying heat treatment was meager, the methods primitive, and the plant crude. Early experiences with alloy steels, both for tool and constructional purposes, were frequently disappointing and only in few instances could they show any advantage. This situation continued until heat treatment methods and appliances had been worked out scientifically.

For instance, high tungsten-chromium steel was a metallurgical curiosity which from the cutting point of view possessed no advantages over Mushet's lower tungsten air-hardening steel until Taylor discovered that a high temperature treatment developed a new type of hardness, namely, red hardness, which is directly responsible for the rapid cutting qualities. Clearly, an increase in our knowledge and improvement of the methods of heat treatment were essential to the development and continued use of all alloy steels.

Therefore, the question "Has full advantage been taken of heat treatment in the application of carbon tool steels?" appears to be a very pertinent one. While there can be no doubt that improvements have been made, an impartial observer would undoubtedly come to the conclusion that much greater care and knowledge are put into the heat treatment of alloy steels than carbon steels. If, as a result of the new interest in carbon steels, these conditions are corrected, there is no doubt but that a wholly new viewpoint as to the utility of the older materials will result.

Factors Making for Quality

To a user of tool steel, and particularly of carbon steel, the most important factor is *quality*. Unfortunately the term, quality of tool steel, is just about as difficult of precise definition as is honesty of a man.

View Taken in 1924 at One of the Plants of Crucible Steel Co. of America

It is the writer's opinion that the only true index of quality is dependability. What can be of greater value to a toolmaker than confidence that the bar of tool steel being used today will behave (in machining, hardening, and production) exactly as did the one used yesterday and the one to be used tomorrow?

In the early days of crucible steel, it was considered that its quality was almost entirely, if not wholly, dependent upon the skill of the melter and teemer in combination with the use of raw materials obtained from certain closely prescribed sources. Later, when the chemist was employed in the art of steel making, these truly essential factors were unwisely discounted; chemical composition then took place of pride in determining quality.

Recently numerous factors have been set up as determinants of tool steel quality. The more important of them are:

1. Use of high grade raw materials;

2. Skillful melting and casting, ensuring rigid control of these operations;

3. Chemical analysis held within well defined and narrow limits;

4. Freedom from such mechanical inclusions as gases, slag, sulphides, and oxides;

5. Skillful mechanical and thermal treatment while converting the ingot into the form in which it is used — bar, sheet, strip, or forging;

6. An end result which assures uniform response to precise heat treatment.

Influence of factors 1, 2, 5, and 6 is fairly clear but the roles played by chemical analysis and mechanical inclusions merit further elucidation.

Apart from the content of sulphur, phosphorus, and possibly silicon, which are usually regarded as impurities, the writer believes that composition plays no part in determining quality. A steel containing 0.65% carbon and 0.60% manganese may be equal in quality to one which contains 1.40% carbon and 0.20% manganese. That does not mean that the two steels will be interchangeable as to service, but it does mean that either steel may be produced with a high degree of uniformity.

Mechanical inclusions, which determine the cleanliness of the steel, play a very important part. They should be held to a minimum by selecting clean raw materials and skillful melting and casting.

As a determinant of quality, the distribution of the impurities and mechanical inclusions in a tool steel is of greater importance than the actual content by weight or volume per cent. There will be little question but that a steel in which a relatively high content of impurities and mechanical inclusions is uniformly distributed in almost impalpable form is more reliable than a steel in which a comparatively small content is badly segregated.

"Body" of a tool steel has a real meaning to a maker of fine steels. Mr. Lantsberry cites the factors which go to make a metal of good body, and presents the view that a carbon steel made according to those principles would be superior to alloy steels in many services, especially if heat treated properly.

Since commercial steel is produced at very high temperatures in gaseous atmospheres and refractory containers, it is impossible to produce a material free from impurities. This is an established fact which is seldom given the consideration it deserves, judging from many current pronouncements upon the influence of inclusions on quality of steels. Another fact which is often overlooked is that impurities and inclusions are a much greater nuisance to the steel maker than to the steel user, because to control them at the very outset it is necessary for the steel maker to crop from 20 to 40% (according to the type of steel) during conversion of the ingot to bloom or billet. It is certain the steel maker would like to avoid this large proportion of scrap. The best that can be said about inclusions, from his standpoint, is that they have forced him to make a close study of casting and forging methods. It has been said by a prominent metallurgist that if the customary methods of manufacture produced steel without impurities, then certain of them would be added deliberately! (This is actually carried out in the case of free-machining steels, both of the mild and stainless types, and the importance of uniform distribution is well recognized. How much more im-

portant, then, is the question of distribution in tool steels!)

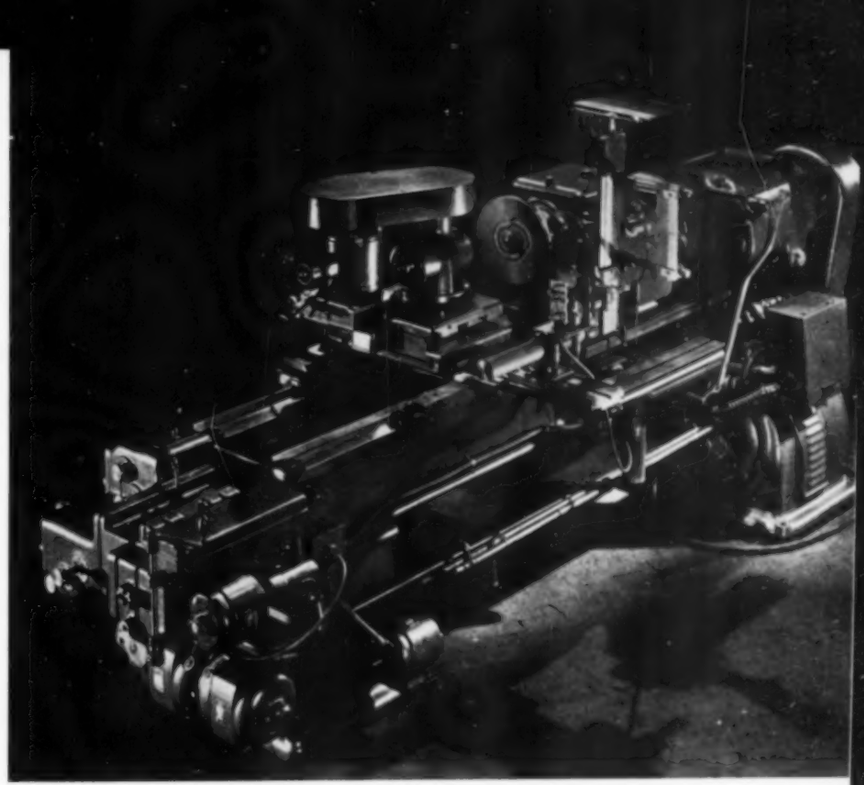
In the present state of our ignorance about the properties of really clean steels, one may speculate whether the complete elimination of impurities would improve the quality of tool steels — particularly carbon tool steels — even though complete elimination is now one of the commercial impossibilities.

While a steel with a very high content of impurities and mechanical inclusions necessarily has a quality which can only be regarded as "low," from the tool maker's point of view, it does not necessarily follow that a steel with a very low inclusion content must be of very high quality. This is true only if it is uniformly distributed in particles of almost submicroscopic size. Such steels can be produced only by the use of highest grade raw materials and the exercise of the highest degree of skill in the control of the melting and casting operations. Quality is therefore inherent in the ingot and if it is not, then no subsequent treatment short of remelting can put it there. Furthermore if it is in the ingot, it can be preserved as far as the finished tool only by the exercise of constant care, knowledge, and skill.

In the very early days of crucible steel making, the term body (or more colloquially, "guts") was used to describe this inherent characteristic of the ingot. With the advent of the science of metallography a great deal of scorn has been vented on the term body, because its users could not define it in scientific terms; it was said that "the term seems to have but vague significance." But there never has been any doubt in the mind of the practical man as to what constitutes body.

Proposals have been made to describe this somewhat elusive characteristic by other terms such as "timbre," "personality," and "inherent hardenability." It would appear, however, that these words are no more precise or capable of measurement than the one they attempt to displace and thus merely add to our technical vocabulary, already much overburdened.

The term body is used to qualify many other technical products such as oils, paints, and textiles. It defines characteristics which are in reality a combination of a number of qualities. There seems every reason to continue its use in preference to the introduction of new terms which have no more definite meaning.



With Expensive Machine Tools It Is False Economy to Compromise on Cutters. Photo of cam milling machine, courtesy Monarch Machine Tool Co.

It is true that crucible furnaces have all but disappeared in America, having been ousted by electric arc or induction furnaces. While the latter doubtless can make carbon tool steels of high quality, the crucible process has certain merits which have not been lost sight of in England and in Europe. From the point of view of the tool steel user, the crucible process is a very desirable one for a number of reasons, among which may be mentioned:

1. The choice of raw materials is prescribed to those of the highest grade, since the process is a non-refining one;

2. Temperature control is better because the furnaces used are incapable of attaining temperatures high enough to bring about serious overheating;

3. Ingots are smaller, which gives better control, owing to the larger number of examinations which must be made.

The very nature of the process not only demands but also provides opportunities for taking precautions which are not possible in the larger scale processes. Likewise there is not the same economic objection to scrapping an ingot, whose weight is measured in pounds, because of some minor defect as there is in the case of an ingot in hundred-weights.

by W. P. Sykes
Metallurgist, Cleveland Wire Works
General Electric Co.

POWDER METALLURGY

as illustrated by tungsten

ALL BUT AN INFINITESIMAL TONNAGE of metal is melted in some kind of furnace at one stage or another in its progress into useful forms. Hence the overpowering importance of what text books call pyro metallurgy. But this process is wholly incapable of handling a metal whose melting point is higher than any known refractory.

Tungsten is the most important commercial metal of this sort. The user and fabricator, instead of starting with a pig or an ingot, must work up a powder. "Powder metallurgy" (as distinguished from pyro metallurgy) may therefore be best described by a brief account of the manufacture of tungsten wire for filaments in the lamp industry.

The present process was in the beginning born of necessity, as is usually the case. The extremely high melting point of tungsten (some 6150° F. or 3400° C.) makes this metal especially suitable for a lamp filament; at the same time it places unusual limitations on the methods of working. A starting material in the cast condition was quite out of the question, since necessary refractories in which to melt the metal are unknown, and especially because the highest degree of purity is demanded.

That last phrase is an excuse to mention another interesting aspect of powder metallurgy — namely, the direct reduction of iron. Nearly every proposal for such a process starts with the statement that high temperature reduction of iron ore in a blast furnace introduces impurities into the pig, which must later be refined out again. Most patentees aim to reduce the oxide to metal at a low temperature and separate the tiny iron crystals from the gangue by mechanical means. How to do this and how next to consolidate these iron particles into useful shapes will require a wholly new art of powder metallurgy — something for the future to learn.

Just to round out the picture, it might also be remarked that a sizable percentage of our copper and zinc is produced without passing through a smelting furnace. Oxidized or roasted ores or tailings are leached with sulphuric acid and the resulting solution electrolyzed — that is, pure metal is deposited on cathodes. It just so happens that the easiest way to get these cathode crystals into marketable shape is to melt them and cast them into bars or slabs, so the melting furnace is not entirely eliminated even here. However, it is also true that one of the easiest ways to produce fine powders of these metals used for such purposes as oil-less bearings, as described later, is to regulate operating conditions in the electrolytic tank. Thus the digression rejoins the subject in hand.

Briefly, then, the subject of powder metallurgy concerns the manufacture of very refractory metal or very pure metal, and of some articles made therefrom. It also includes the manufacture of mixtures of such metals, or of more common metals with non-metallic materials or even with metals which would segregate if melted. Finally, it includes the making of porous metal — metallic sponges of one sort or another.

Each of these subdivisions usually comprises an art in itself, sometimes held in a few hands with considerable secrecy. Hence the present author will confine his principal remarks to the metallurgy of tungsten, viewed as a particular phase of powder metallurgy.

Tungsten Powder

The starting material is tungsten powder, produced by reducing the purified oxide, WO_3, in hydrogen. The oxide is stoked in nickel boats through nichrome tubes in which is maintained a flow of hydrogen. The tubes are heated externally by a gas flame and reach a maximum temperature of some 1500° F. near the rear end of the furnace. About two hours is allowed for the complete operation and the boat of reduced metal powder after cooling in hydrogen is removed from the rear of the furnace tube.

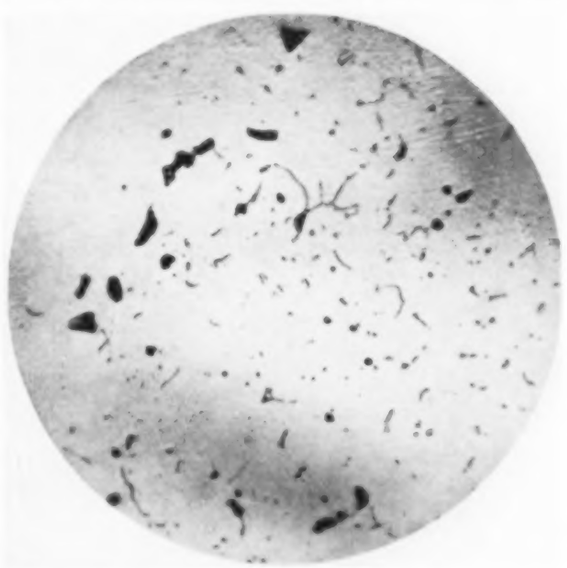
Accumulated metal powder from the reduction furnace is thoroughly mixed by tumbling and sifted through a 250-mesh screen. It is now ready for the pressing operation. In this step a weighed amount is loaded into a steel mold and subjected to a pressure of 20 tons per sq.in. The dimensions of such a pressed bar are ½ in. or ¾ in. square by 24 in. long. Pressure is applied on the long side of the charge through a movable steel plunger and the mold is so constructed that it may be opened by extracting steel pins which, passing through end blocks, hold the sides in place.

After pressing, the tungsten bar is distinctly fragile. It is pushed from the opened mold onto a slab of tungsten or molybdenum and stoked through a so-called sintering furnace at about 2400° F. in a hydrogen atmosphere. This furnace is illustrated on page 26 and consists essentially of an alundum muffle, wound with a resistor of molybdenum ribbon, and equipped with a water-cooled chamber or prolongation in which the tungsten bar may be cooled to room temperature.

This sintering operation imparts considerable strength to the pressed bar, although the shrinkage in volume is very slight. Its density is 12 to 13. The bar is now ready for the high temperature treatment which will put it in shape for subsequent hot working.

In this last mentioned operation, which is known in the shop as "treating," the sintered bar is suspended vertically from a water-cooled clamp while its lower end makes a loose contact with a water-cooled well of mercury through another spring clip of tungsten slabs. A water-cooled hood is now lowered over it and dips into a ring of mercury, thus sealing the interior from the air, and a stream of hydrogen is passed through the inner chamber.

The temperature of the bar is then slowly raised by increasing the voltage in the circuit of which it forms a part. The control of the treating operation is based on the current required to fuse a rod of given weight, size, and lot of tungsten metal. Usually the rod is held for 15 min. at an amperage representing 95% of the so-called fusion amperage. During this



Thoria (Dark Inclusions and Films) in "Treated" Tungsten Rod Before Swaging, at 1000 Diameters. Such treating produces metal substantially free of voids

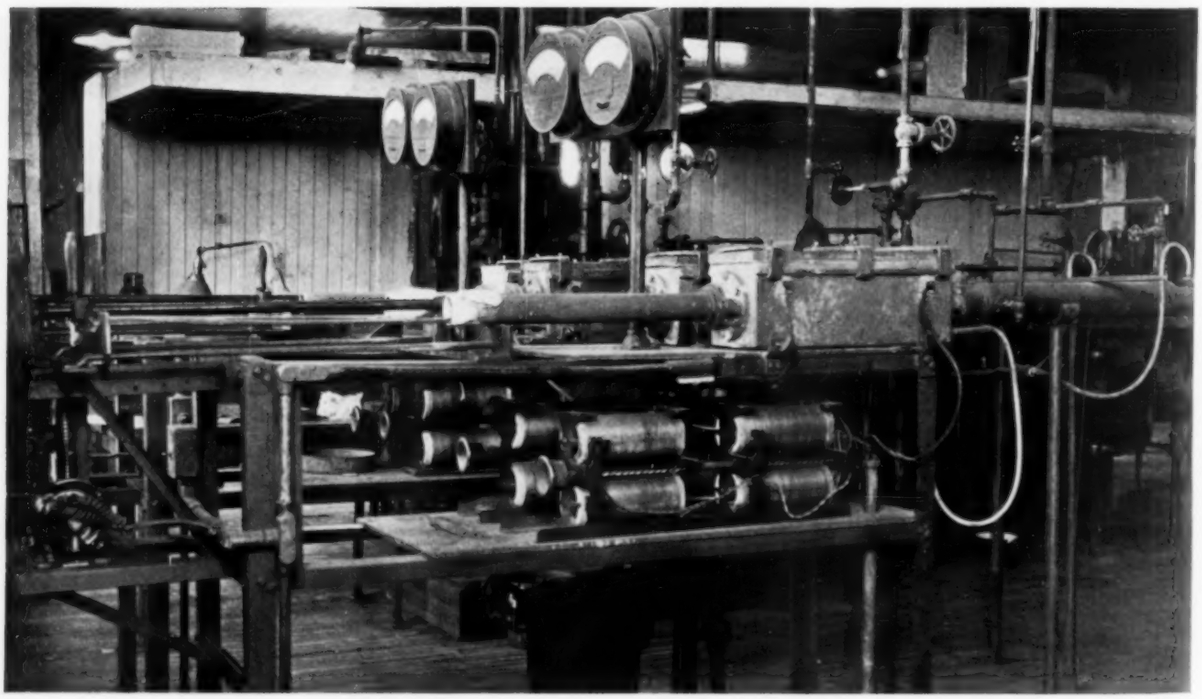
treatment the rod undergoes a linear shrinkage of from 15 to 20% and at the end is substantially free of voids and has a density of 17 to 18. The fracture of the treated bar is crystalline and its hardness is Rockwell C-25 to 35. In fact, the microstructure may be nearly identical with that of a pure metal in the cast condition.

Such a tungsten bar is distinctly brittle at ordinary temperatures, but when heated to 1500 to 1800° F. it may be deformed by hammering. During such deformation it is vital that the metal be kept hot to avoid fracture. For this reason the swaging operation appears to be ideally adapted. In this operation the tungsten rod is heated to some 3000° F. in a hydrogen atmosphere and pushed by hand between the two halves of a revolving die. The two halves of the die fly apart by centrifugal force but are returned by impacts from a surrounding ring of rollers which strike the outer surfaces of the die blocks. Since the bearing surface of the die is relatively narrow and the hot rod is constantly moving forward, the time of contact between hot tungsten and cold die is of short duration and the die always works on hot material.

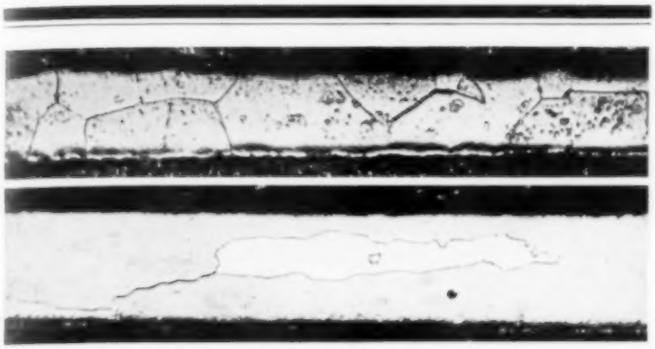
When fracture occurs in the earlier stages of working due to cold deformation, it follows the grain boundaries. Continued working develops a "fibrous" structure in the tungsten which imparts increasing toughness. The temperature may therefore be gradually lowered as the working proceeds. Swaged rod has a density of 18 to 19.

When the rod has been reduced by swaging to about 0.100 in. diameter it is transferred to a draw bench where the reduction continues through tungsten carbide dies. At about 0.050 in. diameter the wire is sufficiently pliable in the cold to be drawn onto reels. Below 0.010 in. diameter diamond dies are used exclusively. While annealing, as understood by steel wire makers, is not necessary, the wire is heated to some extent before passing through the die down to the smallest size. It is possible to draw cold for a few passes, but the tungsten hardens rapidly under these circumstances and wears the die excessively.

By the swaging and drawing operations the tensile strength has been increased enormously until it reaches a unit strength of some 600,000



Battery of Four Tube Furnaces for Sintering Briquettes of Powdered Metal in Proper Atmospheres. Pushers at left; coolers at right; resistors for temperature control below



Above: Microstructure of Thoriated Filament After Burning in Lamp, and Below: "Non-Sag" Structure. Both at 200 diameters. Large grains do not comprise total thickness of wire in dimension perpendicular to plane of polish

lb. per sq.in. in wire of the 0.0005-in. diameter.

Now to return to some of the earlier operations and the factors involved there which affect the final properties of the material:

The particle size of the tungsten powder is one of the most vital factors which enter into the control of the product. This in turn is dependent upon the state of the oxide and the reduction conditions, such as the temperature and the purity of the hydrogen. The control of this factor is even now based upon rules which are mainly empirical in origin.

Control of Grain Size and Shape

It has been fairly well established that, for one important class of material at least, the following relations hold:

1. A fine oxide produces a fine metal powder and conversely a coarse oxide results in a coarse metal powder, under like conditions of reduction.

2. A metal powder of small particle size tends to produce a treated bar of relatively large grain size, while the coarser metal powder results in a smaller grain size. Grain size and orientation is a matter of prime importance to the filament, as is well known.

A tungsten powder which is too coarse or "sandy" will not consolidate well under pressure, while a very "fluffy" metal will be too soft to handle after pressing. It is sometimes necessary to add a little paraffin dissolved in carbon tetrachloride to the metal to improve its pressing characteristics. Generally speaking, the best working properties are obtained in a metal which has a maximum number of particles of size about 0.010 mm. with a fairly rapid decrease in frequency down to 0.003 mm. as finest and up to 0.017 mm. as coarsest.

There are other factors entering into the problem which tend to obscure any simple relationship which may exist. One of the most effective of such factors is the presence in the tungsten oxide, prior to reduction, of certain salts carried over from the purification process. Strangely enough, tungsten metal produced from an extremely pure oxide is of little value as a lamp filament.

In the days of the straight filament lamp one of the chief causes of failure was known as "offsetting." Now in some lots of metal such failures were quite absent, and it developed that these lots had been made from oxide which was baked in fireclay crucibles and contained fractional percentages of silica and alumina. The crucibles were known as Battersea crucibles from their place of origin, and such wire was consequently called "Battersea wire."

Later application of metallographic methods disclosed the fact that this wire, after burning in the lamp, was composed of relatively small grains and a scarcity of single boundaries extending completely across the wire. "Offsetting" on the other hand, resulted directly from the growth of large grains in the glowing wire, with boundaries extending across the full diameter in a plane at right angles to the long axis of the wire. The adjacent grains then proceeded to slip out of alignment along this boundary, resulting in a reduced cross-section of increased resistance and temperatures and eventual failure.

A modification of the Battersea method of preventing grain growth was the addition of a solution of thorium nitrate to the tungsten oxide before reduction. After reduction and treating, swaging and drawing, the thorium oxide particles were well dispersed throughout the wire and effectively restrained grain growth — that is, the thoriated filament, on heating, rapidly achieves a uniform grain size where none can grow at the expense of its neighbors. Its microstructure is illustrated above. The theoretical

aspects of this important fact have been discussed by Dr. Zay Jeffries in several places.

With the advent of the coiled filament and the higher operating temperatures a new set of characteristics was demanded of the filament material. In order to maintain its efficiency the coil must now be able to hold its form, without sag or spread. The structure in the filament which best fulfills these requirements is one of extremely large and long grains. This structure is produced by adding to the tungsten oxide small amounts of sodium, potassium, and silicon as solutions of their salts. In addition to this the reduction of the oxide is carried out in two furnacings following a carefully specified schedule. Both the salt addition and the double reduction appear to be necessary to insure the final so-called non-sag structure in the filament wire, shown in the lower micro, page 27.

Fine crystalline powders of pure metal (as distinguished from flakes used for paints) form the basis of all articles made of pure tungsten, tantalum and thorium, and of their alloys of very high melting point. Also for mixtures of metals with non-metals, like cemented tungsten carbide, and of porous materials, like oil-less bearings. Mr. Sykes in this paper, read before the Milwaukee Chapter, reviews the problems involved, especially those involving tungsten

Another powder alloy is tungsten and copper known as Elkonite. This might be described as a sponge of tungsten which has been allowed to soak up molten copper. It combines high electrical conductivity with good hardness and strength and has been used to advantage for contact electrodes for resistance welders.

In its manufacture the bar of pressed tungsten is placed in a refractory container with a definite amount of copper and heated in a hydrogen atmosphere. The copper melts and is sucked into the voids in the tungsten briquette by capillarity, filling them completely. This process was brought under control quite effectively by mixing lots of tungsten metal of varying particle sizes in order to produce a preliminary aggregate having the desired voids.

Another branch of powder metallurgy of tungsten involves the manufacture of hard tool materials. It started as a search for a substitute for diamond dies in large sizes to be used for drawing tungsten wire. The first success was with an alloy of 90% tungsten with 10% iron. The metal powders were mixed and pressed into the shape of die plates, and heated in hydrogen to a temperature just sufficient to form a small amount of liquid iron-tungsten alloy for cement. The resulting die was relatively hard and wear-resisting and after drilling with a steel needle and diamond dust, served its purpose well. Its microstructures consisted of an iron-tungsten alloy matrix (which had melted) holding grains of tungsten which had not melted but whose angular projections had been melted away.

After this came two other compositions, both improvements. The first was composed of 80% tungsten, 15% cobalt, and 5% chromium, and the second had a composition approximating 80% tungsten, 19.5% chromium, and 0.50% carbon. The latter alloy was sintered in a carbon tube placed within the usual hydrogen muffle; this was necessary in order to maintain the carbon content of the alloy.

Finally came cemented tungsten carbide which surpasses any of its predecessors as a die material and also has attained great importance as a cutting tool for very hard, tough, or abrasive metals and non-metallic articles. It is marketed by various makers under trade names such as Carboloy, Firthite, Widia, or Strauss Metal. Its manufacture has been described in various publications, somewhat as follows;

Tungsten powder of correct grain size is intimately mixed with about 6% its weight of lampblack and heated in controlled atmosphere. The resulting hard but very brittle carbide is pulverized in small ball mills and properly screen sized. Next a weighed amount of binder — commonly powdered cobalt metal — is added and again the mixture is ball-milled until the carbide particles are well smeared with the binder. Next this mixture is pressed by dies in a hydraulic press into small bars (say ½x¾x6 in.). A "semi-sintering" operation in hydrogen atmosphere at 1500 to 1650° F. converts this bar into something of the coherence of chalk, and

it then is cut into such forms as required for insets into the various tools on order, making proper allowance for about 15% shrinkage in final sintering and for grinding after the tools have been finished. Final sintering is then done in a tube furnace at 2450 to 2800° F. and in a purified hydrogen atmosphere.

As is well known, the resulting cemented carbide is exceedingly hard but somewhat brittle, and hence is used as tips or nibs, brazed in place in carbon steel shanks or holders of appropriate form. The art of powder metallurgy in this field comprises a close control of the essential operations described above. Much work has also been done to adapt the material to specific cutting jobs by adding other carbide-forming metals (such as tantalum) to the tungsten, and by using metallic alloys in place of cobalt.

Returning now to metal powders, thorium metal has been produced by swaging and drawing the pressed metal powder in a process analogous to that described for tungsten. This metal is so active chemically that the sintering or treating operation must be performed in a vacuum or in a very pure inert gas.

Alloys of iron containing up to 30% tungsten or 20% molybdenum can be swaged and drawn into wire from a starting material made by sintering the mixed and pressed powders at a temperature just under the solidus, although such alloys can also be melted.

The metals iron, cobalt, nickel, and copper may be worked from the pressed and sintered powders and drawn into wire in much the same way as is tungsten. If the pure oxides can be obtained, the reduction by hydrogen to the metal is fairly complete at atmospheric pressure. Usually there remain some unreduced nonmetallics, probably complex oxides, which may interfere with drawing at small diameters.

It may be of interest to mention here that a briquette of iron powder as pressed at 20 tons per sq.in. has been observed to have a Brinell hardness of about 86. This same piece after sintering for one hour at 2730° F. (1500° C.) had dropped in hardness to 60 Brinell. This suggests that in the case of iron the pressure had resulted in a sort of mechanical welding, producing a fine-grained aggregate, whereas subsequent sintering just below the melting point was attended by marked grain growth and consequent softening. In the pressed condition, however, the metal could have been worked only to a very limited extent without disintegration.

Oil-less Bearings

There have been on the market for some years several self-lubricating or "oil-less" bearings made of mixtures of metal powders and graphite. They are very useful for small industrial or domestic motors or other equipment which must operate indefinitely with little or no attention. Lately they have been widely used by the automobile industry as anti-squeak spring inserts, and for minor bearings.

They are ordinarily made of well-mixed copper and tin powders (about 10 to 1 in weight) with a few per cent of graphite. Measured amounts are pressed into sleeves or plates in dies of great accuracy, so the final shape will need little or no finishing to size other than burnishing or drawing over a sizing arbor. After pressing, the parts are heated to 1450 to 1650° F. (to bond the particles without causing much shrinkage) and quenched in lubricating oil. Oil is thus drawn into the metallic sponge and held there until squeezed out by pressure from the journal, and an external supply of oil works through the spongy bushing as needed.

Similar bearings made of powdered iron and graphite are now being made. They are said to be heat treatable, in the sense that some combination of iron and carbon into steely composition is practicable. Resulting bearings have compressive strengths up to 80,000 lb. per sq.in., as compared to about 35,000 for the spongy bronzes above mentioned, and an apparent hardness two or three times as great.

From a manufacturing standpoint articles from powdered metal look attractive, for there should be little or no machine scrap. In this they resemble die castings. This branch of the art of powder metallurgy comprises the choice of original particle size so the correct amount of microscopic voids (some 35%) will exist in the final bearing, the compounding by analysis to give the proper strength and toughness, the design and operation of rapid-acting precision presses and dies, and the control of heat treatment for apparent density and other mechanical properties.

by Charles H. Jennings
Westinghouse Research Laboratories
East Pittsburgh, Pa.

HEAVY WELDINGS

for Boulder dam

BOULDER DAM, ITS POWER PLANT and accompanying works, now being constructed on the Colorado River, is notable for the unrestricted use of welding in the construction of such vital parts as the penstocks, generators, gates in the intake towers, and needle valves. This large use of welding is the result of the success of the many structures built under the A. S. M. E. boiler code (unfired pressure vessel section on fusion welding).

In order to appreciate thoroughly the magnitude and importance of the cylinder gates and nose liners to be described in this article, it should be first understood by the reader that two power plants are to be constructed at the down-stream toe of the new dam, facing each other across the gorge. These buildings will hold 17 hydraulic turbines, which together will generate 1,835,000 hp. Four steel lined penstocks bring the water through tunnels driven in the canyon walls, two on each side, to the 17 hydraulic turbines. The inlet end of each penstock (a conduit 30 ft. in diameter) occupies the entire bottom of a buttressed gate-tower, founded on the bedrock just above the dam, and rising like a chimney, 30 ft. across inside and nearly 340 ft. high to overtop the reservoir level.

Through the bottom walls of this massive tower are cut twelve openings, about 9 ft. high by 7 ft. broad, spaced evenly around the circle. The "nose liners" which frame these openings form a circular frame about 37 ft. outside diameter and comprise the huge structure shown on the opposite page.

Water on its way from the reservoir above the dam to the hydraulic turbines enters the gate tower through these openings from all directions, and passes downward through the bottom into the penstock tunnel and thence through branch piping to the wheels. To shut off the water it is necessary to lower 32-ft. cylindrical gates, from just above, into place so that they fit tight against the nose liners at their top and bottom circumferences. The water pressure is normal to the surface at all points of this great hoop, and it therefore acts as a complete arch. The outer surface is a smooth 2-in. plate; the inner side is heavily reinforced with 2¾-in. ribs. The center is open, having no cross bracing, since a similar gate is built into each tower about half way up, and there must be no obstruction to the passage of water from above.

Obviously the collapsing forces impressed by the head of water on these circular gates are enormous. Choice of welded copper-bearing steel by the supervising engineers is a tribute to the proven strength of Class 2 work done under the A. S. M. E. code, as well as to the adaptability

of this type of construction to unusually large members.

Gates and nose liners were fabricated in segments small enough for rail shipment; six of them were required to make a complete circle. After each segment was welded it was strain annealed. Segments are assembled at the site by stainless steel bolts. The only welding required after annealing is a small seal weld at parting joints of the nose liners after erection.

General Specifications

The plates were to be accurately cut to shape and the edges prepared so as to allow thorough fusion and complete penetration. Flame cutting was permitted, providing it was done by machine. Contour irregularities at points of critical stress were to be removed by welding and grinding.

The welding process was to be under control at all times and only skilled welders capable of meeting the qualification tests for welders as specified in the "Rules for the Fusion Process of Welding, Class 2 of the A. S. M. E. Boiler Construction Code, Unfired Pressure Vessel Section" were permitted to work. Each deposited layer of weld metal was to be thoroughly cleaned and peened before depositing the succeeding layer. Finished welds were to be reasonably smooth and free from grooves, depressions, undercut, and other irregularities.

After each segment was completely welded, it was to be annealed for a time not less than 1 hr. per in. of maximum thickness of metal and allowed to cool slowly in the furnace.

Copper-bearing open-hearth steel plate was specified, it to have a minimum "yield strength" (0.2% elongation) of 24,000 lb. per sq.in. The average chemical analysis of the plate supplied was 0.23% C, 0.56% Mn, 0.24% Cu, 0.03% P, and 0.03% S; representative tensile values are yield strength, 27,000 lb. per sq.in.; ultimate strength, 58,500 lb. per sq.in.; elongation in 2 in., 36%.

Qualification of a crew of 80 to pass the requirements of Class 2 welding was a necessary preliminary. A suitable training course includes a day of demonstration and special instruction to inform the welder of the proper welding technique and the quality of weld required, followed by five to ten days' practice under the supervision of the instructor. (The exact length of this practice period depends upon the ability of the welder.)

Weldings That Are Weldings. One of eight nose liners for penstock gates, Boulder Dam, made by Westinghouse Electric & Mfg. Co.

Practice welding should consist essentially of butt welds on plates about 15 in. long with thickness corresponding to the maximum size of welded joint in the structure, and subjecting them to a nick-break test. When the fracture is free from gas holes, slag inclusions, and poor fusion, the welder will be capable of making welds that will meet the Code's requirement for tensile strength, ductility, and soundness. (This conclusion, of course, is dependent upon the use of a high quality welding electrode which has been proven capable of producing welds of sufficient quality.) Typical nick-break fractures are shown in the view on the next page.

During the practice period he should also practice on fillet welds, if they are to be used on the structure.

In cases where a welder fails to pass the final tests he should be told the reasons for failure and given special instructions on how to correct them. He should then practice for sev-

Gates for Boulder Dam penstocks are so large and heavy that even the largest machine tools had to be remade before the segments could be finished. Mr. Jennings, who was advisor on welding practice, describes a few of the problems met in producing large weldings to very small tolerances. About 10 tons of welding rod was required for 8½ miles of triple-run seam

eral days before making another test plate.

Class 2 welding requires that (*a*) full section tensile specimens must possess a strength not less than the minimum specified for the steel, (*b*) tensile strength of a reduced section specimen to be not less than 95% of the above, (*c*) 20% elongation by free bend, and (*d*) nick-break fracture to show sound, clean metal with not more than six gas pockets $\frac{1}{16}$ in. maximum diameter per sq.in. of weld surface exposed in the fracture. To meet these values all welds must be made with a high quality fluxed electrode, and the latter were of the Westinghouse "crucible weld" type. It is worthy of note that the quality of the welds made actually met all the physical requirements of Class 1 welding.

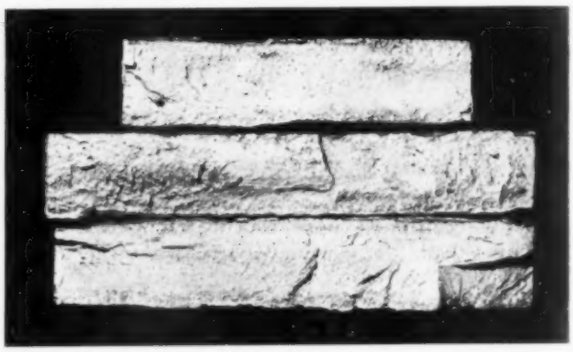
Qualification specimens made by welders produced the following typical results:

Full Section Tensile — Failure in the parent metal at an ultimate strength equal to that at parent metal (55,000 to 65,000 lb. per sq.in.).

Reduced Section Tensile — Failure in the parent metal; strength as above.

Ductility — 30 to 50% by free bend.

Nick-Break — Maximum of two holes, each less than $\frac{1}{16}$ in. diameter, in a specimen with 4½ sq.in. of exposed surface in the fracture.



Fractures of Test Welds in 2-In. Plate. If a workman can make a sound joint of this sort he can pass the Code's requirements for Class 2 welding

Welding Procedure

Electrodes $\frac{3}{16}$ in. diameter were used primarily for tacking and for depositing the first beads in the bottom of butt welds where the gap was too narrow to obtain good penetration with larger electrodes. Electrodes of ¼ in. or $\frac{5}{16}$ in. diameter, depending on the size and location of the joint, were used for butt welds. All fillet welds were made with ¼-in. electrodes.

As a consequence of the particular design of the structures, it was necessary to make most of the joints of the single bevel type. The included angle between the kerfs was held as closely as possible to 45° (and the included angle between the kerfs of the few single and double vee joints in the pieces was held to about 40°). At first thought these angles might seem small, but extensive tests indicated they would give the best results with this thick plate. The only difficulty that might be encountered would be to obtain good penetration at the bottom, and this was completely eliminated by slightly spacing the abutting edges and depositing the first bead with small electrodes.

The advantages of the small included angle are three: (*a*) It reduces the amount of weld metal required in making a joint, thereby reducing the time and cost; (*b*) the reduced amount of deposited weld metal reduces the local heating in the structure, and reduces the residual stresses; (*c*) it enables one to weld the full width of the widest joints at a single pass without excessive weaving. (If a very wide weave is used with fluxed electrodes, the pool of molten metal becomes too large, thereby overheating the deposited weld metal and undercutting.)

As mentioned before, fluxed electrodes primarily adapted for horizontal welding were used. Likewise large electrodes and high welding speeds can be obtained by horizontal welding. Consequently the gates were tilted in various positions during fabrication so that all

joints could be welded in such a position. When making fillet welds the structures were tilted approximately 45° in order to form a trough something like a butt weld.

Tilting of the complete segments into the many necessary welding positions was a large task; consequently a number of sub-assemblies were first made in simple fixtures.

Fabrication of Gates

After welding the necessary individual details, the complete segments (with the exception of the parting plates, which are attached to the ends of the reinforcing ribs) were assembled in a jig and tack welded together into the massive piece shown on this page. Tack welds were made with fluxed electrodes and were approximately ½x6 in. Segments were then removed from the assembly jig and completely welded together. This being completed, the ends of the ribs were machined and beveled and parting plates attached and butt welded into position.

The gate segment photographed on this page has been tilted in approximately a 45° position for making the fillet welds between the central portion of the reinforcing ribs and the shell plate. These, and all other principal welds, were made in a series of 8-in. lengths, each length built the full thickness of the finished weld, working progressively from the center of the segment toward the outer edges. Three layers, made with ¼-in. electrodes, were required. This procedure eliminated any welds smaller than finished size, and was necessary because if welds were made by depositing single layers the full length of the joints, the uneven heating and cooling of the thick, heavy members would cause cracks in the partially welded joints. Constructing the welds so that all but the immediate 8 in. being welded were full size eliminated this difficulty.

Butt welds were also made by progressing from the center of the joint toward the ends.

In order to weld the rib spacers and parting plates properly in place the segments were mounted on a heavy fixture. The principal parts of the fixture are a flanged shaft, a relic of battleship work being done at the conclusion of the War, mounted horizontally on two large bearing pedestals from a rolling mill motor, raised high off the floor on some standard shop parallels, and a cradle fabricated from structural steel and pivoted to the large flange on the shaft.

The fixture was completed by heavy chain blocks attached at the rear of the cradle for tilting the gate segment as desired. After the segment was properly fixed in the cradle it could be rotated by a line from an overhead crane and locked in position by a large wooden clamp between the bearings. When the crane had set the segment at the proper angle, the two welders could get a great number of correct welding positions by using the chain block at the rear to tilt the segment fore and aft in the pivoted cradle.

In addition to the above the following general rules were followed:

1. All layers of deposited weld metal were peened with a blunt nosed peening tool in a light chipping ham-

Gate Segment Tilted so Angle Between Plate and Stiffener Forms a Horizontal Trough for Rapid Welding. Note position of tack welds

mer, to reduce residual stresses and to clean the weld. The peening operation was carried out immediately after the deposition of each 6 to 8 in. of deposited metal, before it and the adjoining metal became cold.

2. After welding was once started on a gate segment it was continued, as nearly as possible, to completion without interruption. This procedure prevented the segments from being successively heated and cooled and consequently reduced the thermal strain.

3. All tack welds were chipped out as reached, because of the danger of welding over a tack that contained an initial crack.

4. Special attention was given by each operator to all craters. For the best results it was found desirable to fill all craters before breaking the arc, by lengthening the arc slowly before breaking it.

Nose liners, as shown on page 31, were made in the same general manner as the cylinder gates, in that individual sections were separately welded and then assembled in a jig and tack welded together. Numerous temporary braces were added to prevent distortion.

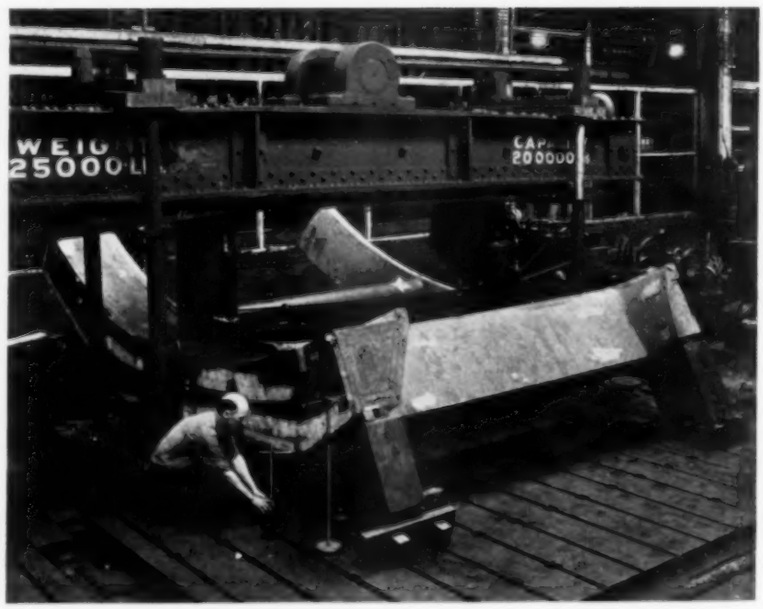
In order to tilt the nose liners so that all welding could be done in a horizontal plane, they were suspended from the overhead cranes—a quick, cheap means of support which turned out to be highly satisfactory.

The complete procedure for the nose liners is long and complicated; it is sufficient to state that the sequence of welding was arranged so as to develop the minimum amount of handling and the minimum amount of distortion or warpage of the finished product.

After completing the welding of each gate or nose liner segment, it was strain relieved in an electrically heated furnace with a car bottom at a temperature of approximately 1300° F. The annealing cycle consisted of 18 hr. to bring the furnace up to temperature, 3 hr. soaking time at the required temperature, and 14 hr. to cool the furnace to 100° F. before removing the annealed segments from the furnace.

Any warpage was effectively corrected by placing weights on top of the segments and proper supports underneath them, causing the fabricated parts to bend back into their proper shape during the annealing process. Sometimes slight deviations beyond allowable tolerances remained, and because of the comparatively slight amount of finish allowed, it was found necessary to do some cold straightening. The fabricated parts being approximately 11x16 ft. in size, a press large enough was not available, so the one photographed below was rigged up from parts available about the shop. The base was the heavy cast iron floor already in position, the strongback was a two-crane lifting beam, and the uprights four turbo generator bolts of nickel steel. Power was from jacks of 800 tons capacity and the pumps were from hydraulic presses formerly used for pressing couplings and other rotating elements on shafts.

The maximum out of round on the finished gate segment was ± ¼ in. on 32 ft. diameter. Actual metal-to-metal contact in service is made between monel metal seats, bolted on and finished to 0.002 in. tolerance.



Straightening Press Made of Floor Plate, Lifting Beam, Generator Bolts and Hydraulic Jacks

By N. Ransohoff
Cincinnati, Ohio

DE-SCALING FORGINGS

by tumbling in weak acid

MUCH PUBLICITY HAS BEEN GIVEN TO recent improvements in heat treating operations and equipment which have minimized the production of scale on the articles. In some instances the extreme of excellence has been reached, in the form of bright surfaces, free even of tarnish, fresh from an annealing operation. These are the exception rather than the rule, however, and by far the large majority of finishing departments will find an economical balance to lie with a combination of equipment and operations which keeps the amount of scale at a minimum and then removes this scale cleanly and efficiently.

It is the purpose of this present note to describe briefly some recently developed equipment which may be introduced into the production line and has been so utilized for the removal of scale from steel forgings. Half-way measures in this operation can no longer be tolerated in a number of important operations, owing to the harmful effect of even very small quantities of scale on the tools used in subsequent machining, forming, and coining.

Conventional methods of scale removal have relied upon variations of two main ideas — *(a)* abrasion, that is, tumbling or sandblasting and *(b)* solution, that is, pickling or electrolysis. While the case for the solution method of scale removal has been stated at length by Mr. Weaver in a series of articles in METAL PROGRESS during 1931, it may as well be admitted that many cleaning departments now in operation must be segregated from other manufacturing operations due to the nuisance created by dust, noise, or fumes. This condition may now be corrected by well-designed and self-contained units of equipment. In most cases collateral advantages of real worth will result from such modernized cleaning devices — this in addition to the enhanced morale of workmen occupying a shop where close attention is given to control dust, dirt and fumes.

Cups Present Problem

As an instance, in a Cleveland plant engaged in extensive forging operations, machining processes on certain parts were found to be relatively costly, due to the residue of scale left on the parts after they came from the tumbling room, where conventional type tumbling barrels

were depended upon to clean up the forgings. This was especially troublesome on a cup-shaped part which was quite thoroughly cleaned on the outside but reached the machine shop with considerable scale remaining in the deep recess. Wear and tear on tools was unreasonably high, and after considerable experiment with tumbling materials, an entirely new tumbling equipment similar to the one sketched on this page was installed.

While atmospheric control of all heating operations will mitigate scale, the problem of cleaning oxidized surfaces will usually remain. Mr. Ransohoff recommends a combination operation of tumbling in an inhibited acid solution for best results

Rough forgings are now brought to this machine in weighed buggies and discharged into a power-operated loading skip (like the ones used on large cement mixers) which charges the first section, or tumbling chamber. This chamber is loaded with hardened stainless steel stars and steel grit, the weight of the tumbling material exceeding the weight of work to be tumbled, so that the work floats in the tumbling material and the parts seldom touch. Thus sharp corners and intricacies of design are preserved.

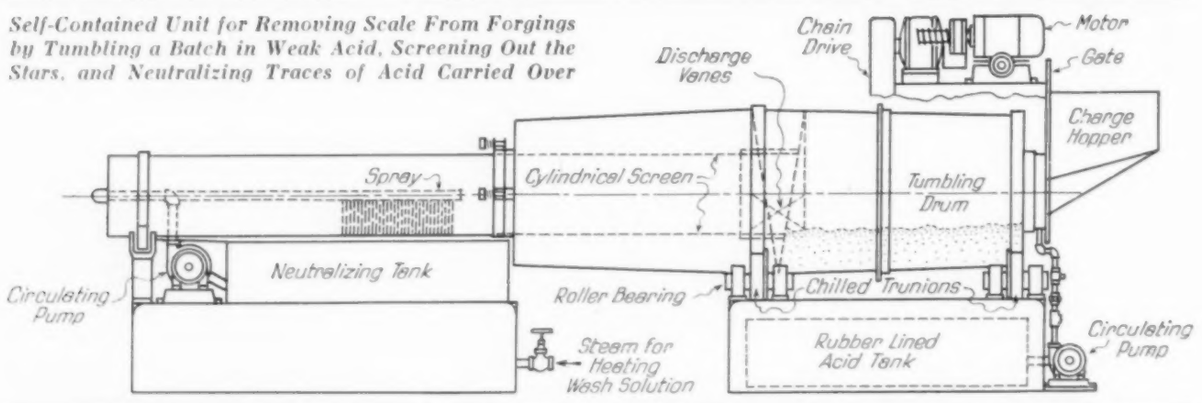
A cold pickle solution (2% acid) is kept flowing over the work by a circulating pump, drawing acid from a storage tank under the drum. The solvent action of the acid loosens the scale, and the stars remove it. Detached scale is carried by the flowing acid to the tank below, where it settles and is periodically removed. Deep recesses in cup-shaped parts may thus be as thoroughly cleaned as the exterior surfaces.

The charge is held in this first drum until scale is removed, the scouring process continuing as long as the drum rotates. Reversal of the direction of rotation discharges the entire contents into a cone-shaped section forward, which screens the work from the tumbling material. When the drum is again rotated in the original direction, the tumbling material (stars and grit) is automatically returned to the tumbling section, ready to start work on the next batch of parts, and the clean parts go on to the washing drum.

This washer rotates continuously. Tumbling sludge is thoroughly removed by a hot basic cleaning compound which is circulated from a storage tank just below. All acid remaining on the parts is thus neutralized and the work reaches the draining section at a temperature sufficiently high to dry the parts thoroughly by evaporation. The work emerges at the end of the machine at convenient height to spill into shop receptacles.

Adoption of this method of cleaning — a combination of abrasion and solution — not only removed the scale perfectly, with resultant machining economies, but tripled the output of the tumbling operation, which had sometimes

Self-Contained Unit for Removing Scale From Forgings by Tumbling a Batch in Weak Acid, Screening Out the Stars, and Neutralizing Traces of Acid Carried Over



developed a "bottle neck." The plant accountant also found an unexpected margin of profit in the better finish given to those parts that required plating, lacquering and the other finishing items now demanded by the ultimate consumer. Once again it was demonstrated that a cleaner finishing operation resulted in a better quality of surface, and in achieving this improvement in quality, fewer parts were rejected on inspection.

Economical, speedy, and thorough removal of scale becomes not only desirable but absolutely essential when preparing work for coin pressing operations, and a cleaning process similar to the one just described is being used in a large plant in the Detroit district making generator parts.

Here the acid tumbling, while in itself a batch operation, is installed as part of a straight-line production.

Forgings come in on a belt and are discharged into a hopper at the charging end of the de-scaling unit. When the tumbler has been emptied of its work and the tumbling material has had time to separate and return to the barrel, as described above, the operator opens the hopper gate and the accumulated batch of rough forgings drops into the revolving drum. The preceding batch of cleaned forgings travels on through the washing part of the machine, to be neutralized, and is discharged in a controlled stream onto a moving belt which takes the parts to the coining presses.

An inhibited sulphuric acid solution (4% strength) is used in this case. The tumbling section and the extension cone are made of steel plate lined with $\frac{1}{8}$ in. of rubber, vulcanized in the shell. They revolve at 18 r.p.m. Washing and draining drums revolve at a lower speed, about 9 r.p.m., to give ample time for neutralizing and drying. The equipment handles 3000 lb. of work per batch; an advantage is that different batches cannot intermix as every drum is completely rid of one batch before the following batch reaches it.

Parts requiring coin pressing for final finish, of course, must be perfectly free from scale and the process described has done this at a cost of about 30% of the previously used methods. This estimate has been derived from a steady operation on parts going to the coining presses. On work not destined for the coining presses and not requiring high ultimate finish — such as cranks, control levers, and cheap tools for automobile kits — the equipment may be operated as a dry tumbling unit.

Small Automotive Part in Three Steps — Forged, De-Scaled, and Coined. Satisfactory coining operations require complete freedom from scale

by Howard S. Taylor
Department of Metallurgy
Stanford University

QUENCHED STEEL

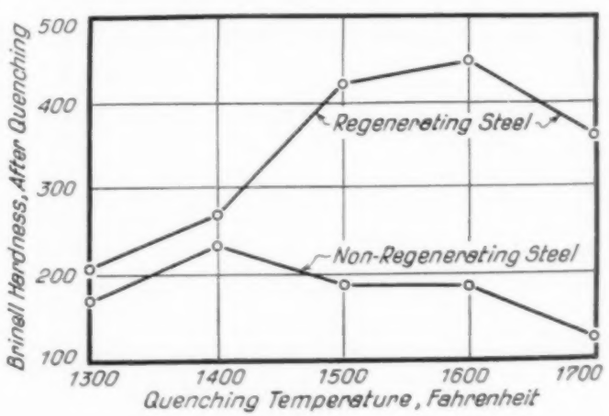
hardness related to normality

STUDIES OF LOW CARBON STEELS have shown that, contrary to the belief accepted a few years ago, some steels would markedly increase in hardness when quenched in cold water from above the critical range. Again, other steels of similar chemical analysis failed to harden after such a treatment. This pronounced difference in behavior can be shown by a simple test originally reported by Prof. W. J. Crook of Stanford University to *Transactions*, American Society for Steel Treating, September, 1929, which consists in heating a series of test pieces at increasing temperatures from 1300 to 1700° F., quenching in cold water and determining the hardness of each piece. He has designated this procedure a "regeneration test" and the steel is said to be "regenerating" or "non-regenerating" if it does or does not possess the ability to harden to some predetermined value. A number of structural and low carbon steels have been studied and classified in this way.

For low carbon steels, of S.A.E. 1020 class, it would appear that the limiting hardness value should be in the neighborhood of 350 Brinell; that is, a steel containing 0.15 to 0.25% carbon that failed to develop a hardness of 350 Brinell would be considered as non-regenerating. This should hold true, at least for sections less than ¾ in. thick. When, in the past, authorities have stated that low carbon steels could not be hardened appreciably, they were considering steels that would now be classed as non-regenerating.

If the data obtained in a regeneration test be plotted, curves such as are shown in the figure below will result. While an examination of over a hundred such curves reveals wide variations, and those for some non-regenerating steels show an increasing quench temperature, the maximum hardness attainable in this class is never very

Difference in Hardenability of Representative Regenerating and Non-Regenerating Steels (Low Carbon)



great; in fact, they do not harden, in the accepted sense of the word. (Curves for some regenerating steels show a slight drop in hardness for temperatures above 1600° F. followed by a second increase, but this is apparently unrelated to the following discussion.) For steels with approximately 0.20% carbon, a single specimen quenched from 1600° F. will be satisfactory for the regeneration test, since, in general, this develops the greatest hardness.

It will now be my aim to show a correlation between the above-described test and the McQuaid-Ehn test for "normality," which is commonly used for determining whether or not a low carbon steel is capable of being satisfactorily case hardened. While nearly all the investigators agree as to the value of the latter test, statements frequently have deplored the fact that it cannot be carried out on low carbon steels without the operation of carburizing, which may or may not change the characteristics of the steel.

Data on Steels Tested

Steel	Chemical Composition					Hardness		Microstructure
	C	Mn	S	P	Si	Rockwell	Brinell	
B-1	0.21	0.42	0.059	0.074	0.15	C-44	419	Quite normal
B-2	0.17	0.56	0.030	0.015	0.17	C-39	367	Normal
B-3†	0.19	0.48	0.031	0.022	0.19	C-45	430	Quite normal
B-4	0.21	0.52	0.029	0.010	0.05	C-19	220	Very abnormal
B-5	0.26	0.59	0.059	0.033	0.28	C-49	476	Nearly normal
B-6	0.07	0.79	0.145	0.104	0.06	C-21	230	Somewhat abnormal
B-7	0.27	0.61	0.063	0.038	0.28	C-45	430	Normal
B-8	0.21	0.56	0.030	0.010	0.05	C-19	220	Very abnormal

† B-3 contained 3.44% Ni and 0.16 Cu

Classification by Normality

Eight low carbon steels were selected at random and subjected to both tests. Their chemical composition is given in the table above. With the exception of steel B-3 (a nickel steel, S.A.E. 2320) none of them showed a combined percentage of copper plus nickel exceeding 0.25%. Steels B-2, B-4, and B-8 conform to the S.A.E. 1020 specification; B-6 is apparently a low carbon screw stock; and B-1, B-5, and B-7 are somewhat over the maximum limits for carbon, sulphur, or phosphorus specified for the S.A.E. 1020 series.

These eight steels were machined to ⅝-in. round bars and two sections, about 2 in. long, were cut from each bar. They were packed in a special carburizing mixture, rich in hydrocarbons, carburized for 12 hr. at 1750° F. and cooled slowly in the box. The case structure of each specimen is shown on the next two pages at 100 diameters after etching for 30 sec. with 4% nitric acid in amyl alcohol, the solution being held at a temperature of 130° F. (This etchant, recommended by Berglund and Dearden, was chosen because it renders more marked the contrast between pearlite and cementite.)

The case structure of specimen B-1 is typically normal. The grains are large and of uniform size. Excess cementite appears as a thin network and as narrow spines penetrating the pearlite grains along crystallographic planes. Specimen B-2 is also distinctly a normal steel, only slightly different from the first, even though it etches somewhat darker.

Steel B-3, which was originally chosen for a plain carbon steel, was later found to contain nickel. The effect of the alloy is clearly shown in the extreme fineness of the cementite network and spines, and it is almost impossible to trace the outlines of the grain boundaries. There is no evidence of abnormality in this specimen.

A very abnormal steel, specimen B-4, is next. The pearlite grains are small and the cementite network is thickened. At higher magnifications the typical breakdown of the pearlite was evident.

Specimens B-5 and B-6 are steels which are neither perfectly normal nor very abnormal. In B-5 the pearlite grains, though generally large, are somewhat varied in size; the cementite is more prominent and a distinct thickening is noted. The general structure is good and this steel could be classed as almost normal, and passed as a satisfactory steel.

Specimen B-6, however, presents sharply contrasting structural features; the cementite

network stands out against the nearly structureless pearlite grains. Comparatively few cementite needles penetrate the grains, and these are blunt and thickened. Some large grains are seen, but the rest are small and gathered in clusters as if a single large grain had been divided into several small ones. Without doubt this steel would be classed as somewhat abnormal, and therefore rejected as not passing the McQuaid-Ehn test.

Another normal steel is specimen B-7, classified with B-1 and B-2 — distinctly more normal than B-5.

Steel B-8 is very abnormal and its structure appears similar to that of specimen B-4. The fine-grained pearlite is surrounded by a thickened cementite network which, under higher magnification, is seen to be surrounded by free ferrite.

In none of these eight steels is there doubt as to whether it should be classed as normal or abnormal. B-1, B-3, B-7, B-2, and B-5 could be certified as having successfully passed the McQuaid-Ehn test; specimens B-6, B-4, and B-8 would have been rejected.

Additional sections were cut from the original bars of the same eight steels, and machined to cubes approximately ⅝ in. on a side. These cubes were heated at 1600° F. for a period of 30 min. and quenched rapidly in running water. One side of each cube was ground smooth and tests were made for hardness. Rockwell hardness readings were then converted to equivalent Brinell numbers, with results as shown in the table on page 39.

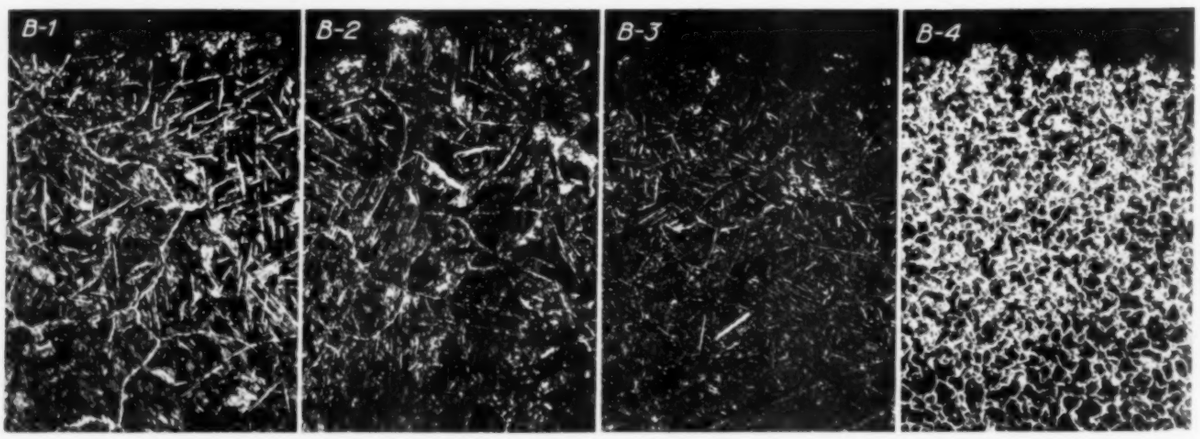
Arbitrarily setting a hardness value of 350 Brinell as the dividing line between regenerating and non-regenerating steels, the eight would arrange themselves as follows in order of hardest steels first: Regenerating steels are B-5, B-3, B-7, B-1 and B-2. Non-regenerating steels are B-6, B-4 and B-8.

Professors Crook and Taylor have found that some plain carbon steels of carburizing grade (probably poorly deoxidized, because they are low in silicon) do not harden if water quenched from 1600° F. Such steels are now shown to be distinctly abnormal after the McQuaid-Ehn test, and the author believes that a hardness measurement before and after the simple quench will indicate whether or not a steel will carburize satisfactorily.

Comparing the Two Classifications

It is of interest to compare the classification made on the two bases, and this is done in the table on the opposite page.

The horizontal line in this table marks the division between normal and abnormal steels on the one hand, and between regenerating and non-regenerating steels on the other. The groups have the same members, as the three



Structures of Some Soft Steels After McQuaid-Ehn Test. Etched and magnified 100 diameters

steels that are distinctly abnormal are also definitely non-regenerating.

In its entirety the group is the same in both tests, although the actual positions of the several steels are decidedly different. Specimen B-5 has been considered somewhat less normal than the other normal steels, but it developed the highest hardness on quenching. Specimen

Structure in McQuaid-Ehn Test	Hardness in Regeneration Test
B-1, Distinctly normal	B-5, 476
B-3, Distinctly normal	B-3, 430
B-7, Normal	B-7, 430
B-2, Normal	B-1, 419
B-5, Nearly normal	B-2, 367
B-6, Somewhat abnormal	B-6, 230
B-4, Very abnormal	B-4, 220
B-8, Very abnormal	B-8, 220

B-1, which was rated first or second by the McQuaid-Ehn test, was placed fourth in the scale of hardness after quenching.

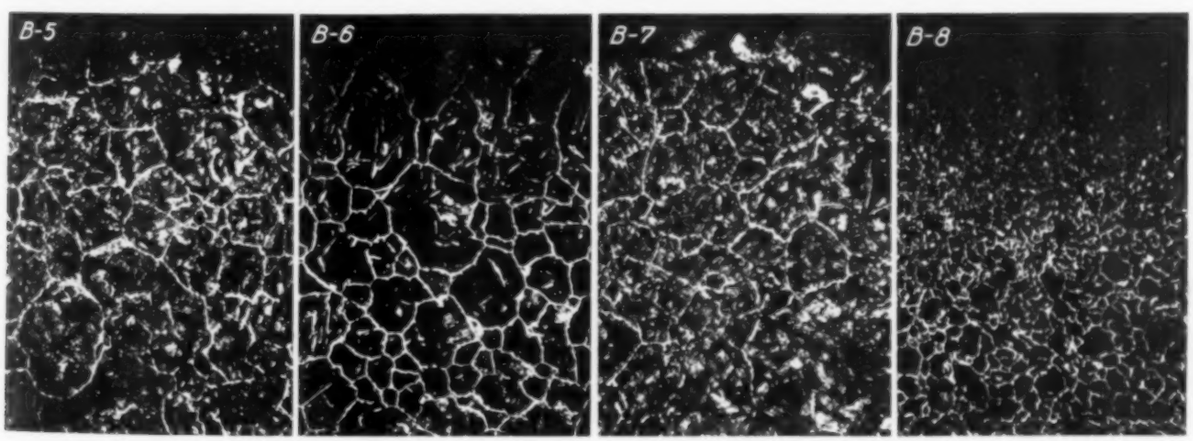
(It will be of interest to note that the completeness of deoxidation apparently has a bearing on the steel's ability to regenerate. Those which failed to regenerate have a silicon content of 0.06% or less, while the others contain at least 0.15%. Other studies, reported by Prof. W. J. Crook to METAL PROGRESS for October, 1930, also indicate that at least 0.60% manganese is necessary in a 0.20% carbon steel if it is to be hardenable.)

In the light of the figures obtained by means of the regeneration test, the microstructures might again be examined. It is possible that a re-grouping of the normal steels might be considered. Specimen B-5 might now be given a rating above B-7, but hardly above B-2. This leads one to conclude that the personal equation enters into any classification that is made on the basis of the carburizing test; but granting that the minimum Brinell hardness value has been chosen, a grouping by means of regeneration is practically automatic. There is a distinct gap between the lowest steel that exceeds 350 Brinell and the highest steel that fails to harden to 350.

Value of Rapid Test

There is an unmistakable difference in the structure of those steels that have been classed as normal and those that have been considered as abnormal. It is to be regretted that none of the steels chosen appeared to be doubtful in microstructure. The regeneration test might classify these borderline steels with greater ease than the carburizing test, but additional work will be required to verify this belief.

This comparison does show that the regeneration test separates the eight steels into two groups exactly as does the McQuaid-Ehn test, and accomplishes this result with greater ease and in less time, and it is believed that the elimination of the personal equation is a decided advantage in favor of the regeneration test.



Structures of Some Soft Steels After McQuaid-Ehn Test. Etched and magnified 100 diameters

CORRESPONDENCE

and foreign letters

Location of Alpha Phase in 18-8 by Magnetic Powders

MOSCOW, U.S.S.R. — Little is known about the nature of the internal changes experienced by certain alloys due to cold deformation, and certain interesting observations along this line have been made at the Moscow Metallurgical Institute, under the present writer's direction, by Miss Pevsner. She used a suspension of magnetic powder in order to disclose this phenomenon in austenitic steels. This method has previously been developed by various physicists to identify the variously magnetized fields in large single crystals of ferromagnetic substances and consists of suspending a magnetic powder in a suitable liquid and then immersing the object to be studied, whereby, after precipitation, the distribution of the powder could be viewed under a microscope. This precipitation can be produced with or without an internal magnetic field.

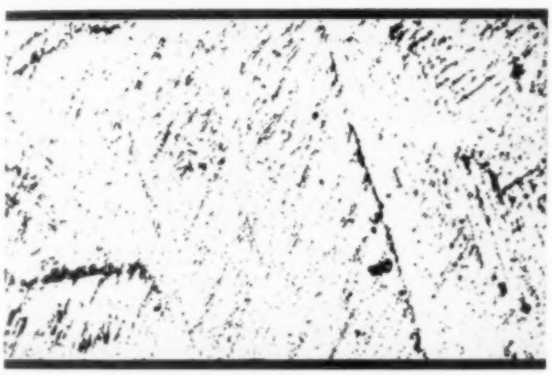
In our work we have followed a similar method for the purpose of determining those places in an 18-8 steel in which the process of transformation of austenite into ferrite takes place under the influence of cold deformation. As an indicator, we have used a thin suspension of powdered ferrous oxide in alcohol. The polished test piece was placed in a small glass vessel on the stage of a vertical microscope. Precipitation took place without the use of an external magnetic field or with very weak magnetic fields.

We expected that the regions in which the transformation of non-magnetic gamma iron into magnetic alpha iron takes place would be indicated by a concentration of precipitated particles. Our experiments have fully substantiated our expectations and have exactly identified the regions of $\gamma \rightarrow \alpha$ transformation in the grains of 18-8. We consider that this is the only known method for determining the true location of this transformation. Etching, as is known, develops slip planes and grain boundaries in alloys that do not change in phase during cold deformation.

Due to the fact that high magnifications could not be used in our experimental method, the specimen was subjected to preliminary heat treatment for the purpose of getting large grains of austenite. Prior to the experiment, we measured the magnetic susceptibility of a non-deformed specimen by means of a highly sensitive magnetometer, and we chose only those specimens which contained no ferrite (within the limits of sensitivity of our apparatus). On such specimens the magnetic powder precipi-

tates uniformly. After deformation by cold work of from 2 to 6%, the specimens became magnetic in nature and enabled us to photograph a perfect picture under the microscope.

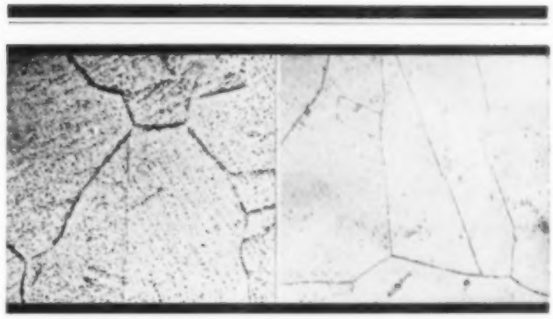
After etching in the usual manner the microstructure of this steel (C 0.13%, Cr 17.7%, Ni 6.84%) in a fully austenitic condition shows large grains, marked out delicately at the boundaries, and crossed at fairly wide intervals by straight parallel traces (twin boundaries or slip bands). A micro of the same steel at 70 magnifications after 5% deformation and precipitation of the magnetic powder is shown herewith. Prior to the precipitation of the powder the specimen was polished very carefully



Coarse-Grained Austenite in 18-8 (Non-Magnetic) Was Cold Worked 5%, Polished, and a Magnetic Powder Precipitated Thereon. View at 70 magnifications shows the formation of alpha to occur at both grain boundaries and slip bands

and was allowed to remain unetched. (A specimen of the deformed steel, etched the usual way, showed the normal picture described above.) Magnetic powder gathered both at grain boundaries and slip bands and proved that the $\gamma \rightarrow \alpha$ process was located specifically in these places. These experiments have been repeated with another 18-8 steel (known as "Avesta," C 0.14%, Cr 18.11%, Ni 7.92%) with similar results.

The magnetic powder mentioned also allows us to prove the existence of the ferrite phase in non-deformed steels. The left-hand view of the pair shows the structure of 18-8 steel at 200 diameters after normal etching. This steel has many fine carbides along the grain boundaries. Measurements have also shown that these steels possess a higher magnetic susceptibility. The right-hand view represents the same steel at 50 diameters after polishing and precipitating the magnetic powder. It is clearly seen that the ferrite phase is located predominantly along the grain boundaries, at which there is a concentration of powder.



Coarse-Grained 18-8, Annealed to Precipitate Carbides at Grain Boundaries. At left is appearance at 200 diameters after etching; at right is appearance at 50 diameters after deposition of magnetic powder

We conclude from this investigation, that the magnetic ferrite phase is formed, in the deformation of 18-8, first along the grain boundaries. Probably this is connected with the fact that the first step in the process of plastic deformation is followed by a rotation of the grains and the creation of stress on the grain boundaries. With increasing deformation slip bands appear, along which the $\gamma \rightarrow \alpha$ transformation also takes place. In highly deformed steels it is difficult to get a satisfactory picture, inasmuch as the specimen becomes too magnetic and the deposition appears in spots.

GEORGE W. AKIMOV

What Does Sorbite Look Like?

ROLLA, Mo. — Now that so much work is being done on the transformation rates of carbon steel, one wonders how to distinguish between pearlite, sorbite, and troostite (as observed under the microscope). Three or four years ago this would have been an easy question to answer, but not now. Bain and Davenport did not consider it worth while to include the name sorbite as a structure in describing their studies on the transformation of austenite at constant sub-critical temperatures, published

A Comparison of Constituents

	Pearlite	Sorbite	Troostite
Interlamellar distance Δ_0	400 to 250 μμ	260 to 100 μμ	100 μμ
Brinell hardness †	200 to 325	325 to 450	450
Characteristic of Associations	Annealed steels	Toughened steels	Tempered steels
Structure at 1000 x	Laminated	Emulsified	Nodular

† Follows Green's Formula: $H \times \Delta_0 = 75.59$ where $\Delta_0 > 250 \mu\mu$

in the *Transactions* of the Iron & Steel Division, A.I.M.E., 1930. Styri, in personal correspondence, agrees with me that sorbite *is* a definite structure with definite properties, although none of the structures illustrated in his excellent series on 1% carbon steel (published as data sheets in METAL PROGRESS since 1931) are labeled as "sorbite." Belaiew, in a paper on the structure of nodular troostite (*Journal*, British Iron & Steel Institute, 1931) also recognizes three degrees of ferrite and cementite coagulation.

As a teacher I would greatly value a publication of photomicrographs, prepared at high, medium and low magnifications by some expert metallographers, showing structures they consider to be pearlite, sorbite, and troostite. (Of course, there is primary and secondary troostite, the latter often a pseudomorph after martensite.) Perhaps this might lead to a guide which many of us could use in describing an observed structure in steel. The table attached gives a tentative comparison.

CHARLES Y. CLAYTON

Rapid Progress of Welding

TURIN, ITALY — As in all other countries, the use of welded steel structures has shown an enormous development in Italy in the last few years. There is perhaps no other European country — excepting Germany — where this has been so rapid and so complete in all fields.

Riveting on structures for buildings, either civil, commercial, or industrial, has been all but abandoned and replaced by welding. The same is true for a great number of other structures subjected to dynamic stresses.

It would be needless to mention the economical and technical reasons for this development in fabricating and erecting practice, as they do not depend on local conditions, and are the same everywhere. On the other hand, it may be interesting to point out a few facts showing some peculiar tendencies in this branch of the Italian industry.

Electric welding has been adopted for the great majority of structures. Reasons for this were brought out at a recent joint meeting of the Society of Structural Engineers and the Association of Italian Metallurgists in Milan. The subject was discussed at length from different points of view by many specialists; the conclusions of the very interesting discussion were in favor of electric welding with few exceptions. These exceptions concern only special cases, like the welding of thin sheets or shapes or welding alloy steels for airplanes.

The wide experience gained in many fields during the last few years has shown that the results obtained by alternating currents are practically the same as those obtained by direct currents. Therefore — for evident reasons of economy and of practical convenience — many large works specializing in this field have adopted alternating current equipment.

Design calculations for welded structures were formerly based on a supposed strength of the joints of only 60% that of the shapes to be welded. In recent months most specifications have raised that limit to 80%, both for tensile and shearing strength. In a few cases 100% has been adopted.

Up to this time not the slightest accident has occurred in any of the important welded structures which can be ascribed to a shortcoming of this new process of fabrication.

FEDERICO GIOLITTI

Solidification of Foundry Alloys

PARIS, FRANCE — The scientific study of foundry practice is based on the laws of solidification of molten alloys and on what has been called "the foundry properties," such as castability, liquation, piping, blistering, and cracking. The highly developed study of the properties of cast metal is based on a knowledge of the constitution of the alloy and the laws of heat treatment, the starting point of which is the equilibrium diagram. Both studies depend also, in a great measure, on the structural morphology — that is to say, on the shape,

?

Can you make this analysis quickly and *positively*

Copper	2.5 to 3.5
Aluminum	3.5 to 4.5
Magnesium	0.08 to 0.12*
Lead	.007 Max.
Cadmium	.005 Max.
Tin	.005 Max.
Zinc	Remainder

BOTH of the above spools were made from this standard diecast alloy. The one on the left was utterly unusable. What was wrong?

A small sample of the alloy used and one and one-half hours work with a spectrographic equipment gave the answer. The Sn was high and the resultant crystal growth caused the spool to be rejected.

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*Many authorities state that Mg (a critical component) cannot be determined in diecast alloys, within these limits, by any but spectrographic methods.

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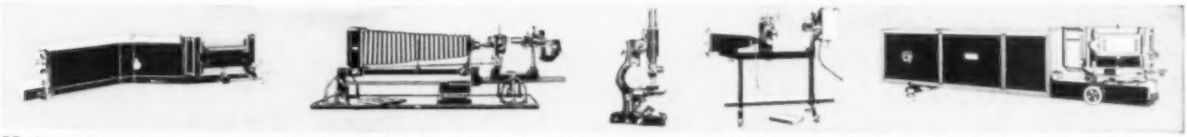

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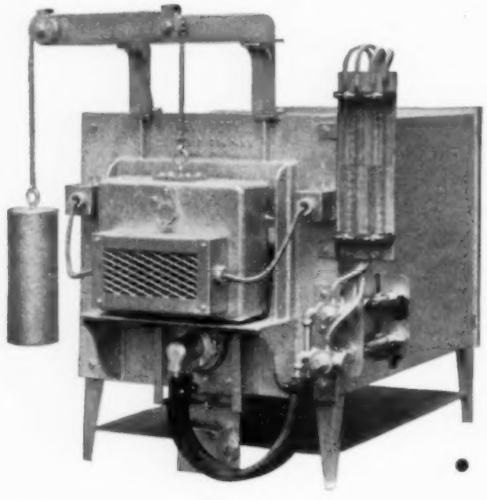

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the dimensions, and the distribution of the sundry constituents — about which the equilibrium diagram does not give any information.

The primary crystals present two principal habits: Dendritic (for solid solutions akin to pure metals) and polyhedric crystals (for intermediate solid solutions or definite compounds). Their number in unit volume depends on the number of crystallization centers formed during unit time in unit volume and on the speed of growth.

Therefore, a good comprehension of the "foundry phenomena" and "foundry properties" is based on the notion that there are three periods during solidification:

1. The crystals of the solid phase are not enough developed, as yet, to be in contact; they are floating in the liquid. The solid phase is discontinuous and the liquid phase is continuous, and both are capable of mutual displacement.

2. The crystals (solid phase) are sufficiently developed to be in contact with each other and incapable of movement; they form a kind of filter through which the mother liquor may circulate. Both phases, solid and liquid, are continuous but only the liquid phase can circulate.

3. Crystals of the solid phase have formed bridges or diaphragms that prevent the liquid from moving from place to place. The solid phase is now continuous and the liquid discontinuous. Relative displacement or important segregation is now impossible.

The comparative importance of the above three periods depends not only upon the solidification diagram and the composition of the alloy (which may define the volumetric proportions of the two phases at every temperature) but also on the crystalline habit and the number of crystals. Thus, in presence of the same number and the same proportion of crystals, the first period is much more important when polyhedric or regular shapes are produced than when dendritic crystals are present.

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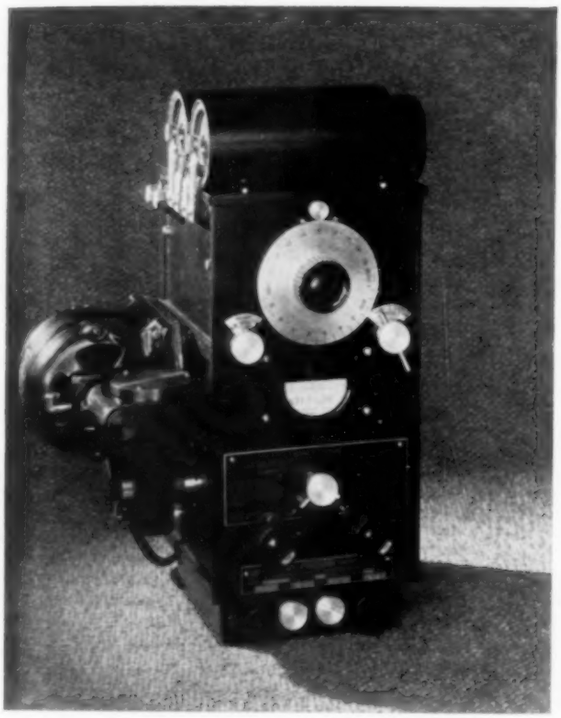

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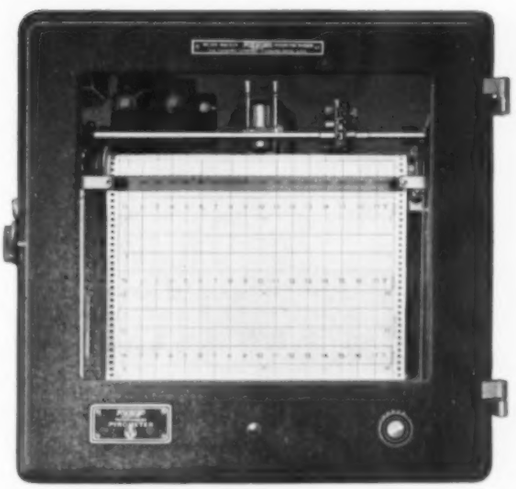

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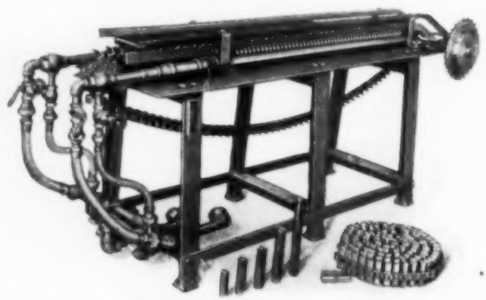

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ARTICLES WORTH READING

General Reviews

Some Steps in Metallurgical Progress, 1908-1933, W. Rosenhain, (Paper for British Institute of Metals) Engineering, Dec., 29, p. 725. . . . . History of Metallurgy at Massachusetts Institute of Technology, C. E. Locke, Technology Review, Jan., p. 135. . . . . One Hundred Years of Sheet Copper, Sheet Metal Worker, Jan., p. 21.

Metallurgical Progress in 1933, T. W. Lippert, Iron Age, Jan., 11, p. 18. . . . . Theoretical Metallurgy During 1933, R. F. Mehl, Mining & Metallurgy, Jan., p. 46. . . . . Electro-Metallurgical Progress in 1933, S. Wernick, Industrial Chemist, Jan., p. 13. . . . . Recent Advances in Metallurgy, A. McCance, Heat Treating & Forging, Jan., p. 25. . . . . Research Developments in 1933, Metal Industry (British) Jan. 12, p. 58.

Iron and Steel Making

Review of Blast Furnace Practice, O. R. Rice, Blast Furnace & Steel Plant, Jan., p. 34. . . . . Improved Auxiliaries at Blast Furnace, W. A. Haven, Steel, Jan. 1, p. 120. . . . . Blast Furnace Developments in 1933, W. A. Haven, Blast Furnace & Steel Plant, Jan., p. 27. . . . . Adjustable Blast Furnace Tuyere for Regulating Combustion Zone, Iron & Coal Trades Review, Jan. 5, p. 12. . . . . Refractory Materials for Blast Furnaces, A. B. Searle, Metallurgia, Jan., p. 85.

Deoxidation of Steel, Metallurgia, Jan., p. 67. . . . Oxide Control in Bottom Casting of Basic Steel, W. J. Reagan, Technical Paper 520, A.I.M.M.E.

Rolling, Piercing and Forging

Rolling Mill Practice, Donald W. Lloyd, Blast Furnace & Steel Plant, Jan., p. 31.

Manufacture of Seamless Tubes, Gilbert Evans, Engineering, Jan. 26, p. 87. . . . . Influence of Oxygen on Piercing of Tubes, Newell Hamilton, Technical Paper 540, A.I.M.M.E.

Technique of Heavy Forging, Ronald Benson, Heat Treating & Forging, Jan., p. 29. . . . . Today's Drop Forging Practice, M. S. Reed, Heat Treating & Forging, Jan., p. 13. . . . . Pressures Required for Coining Operations, C. W. Lucas, American Machinist, Jan. 31, p. 132. . . . . Forces Required for Extrusion (A Series), Erich Siebel, Steel, Feb. 5, p. 36.

Selecting the Proper Metal

How to Select the Right Alloy, H. W. McQuaid, Heat Treating & Forging, Jan., p. 15. . . . . Steels for Industrial Gearing, T. R. Rideout, Machinery, Jan. p. 268. . . . . Silicon Steel With A-C and D-C Excitation, R. F. Edgar, Electrical Engineering, Feb., p. 318

Steels in Marine Engineering, T. H. Burnham, (Paper for Institute of Marine Engineers) Iron & Coal Trades Review, Jan. 12, p. 52; also Metallurgia, Jan., p. 81. . . . . Steam Turbine Development Presents Problems in Design and Metallurgy, C. B. Campbell, Power Plant Engineering, Feb., p. 94. . . . . Materials for Compressors, Paul Hoffman, Machine Design, Jan., p. 25.

Miscellaneous Manufacturing Processes and Products

Valve Seat Inserts, A. T. Colwell, American Machinist, Jan. 31, p. 118. . . . . Setting Inserts at — 90° F., Machinery, Feb., p. 343. . . . . Wear of Piston Rings and Liners, (Paper for Institute of Marine En-

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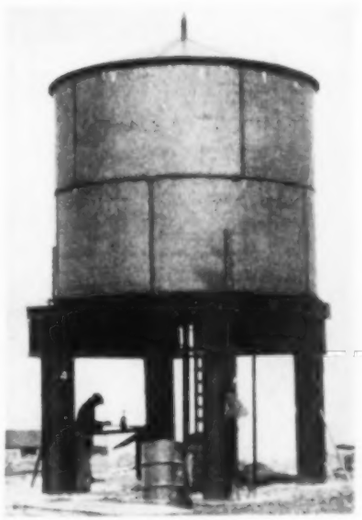

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ARTICLES WORTH READING

gineers) H. J. Young, Metallurgia, Dec., p. 46. . . . . Body Manufacture, Automobile Engineer, Jan., p. 15.

Manufacture of Semi-Elliptic Springs, J. W. Urquhart, Heat Treatment & Forging, Jan., p. 32. . . . .

Vitreous Enamels

Vitreous Enamels and Colors for Cast Iron and Steel, A. England, Foundry Trade Journal, Jan. 4, p. 3. . . . . Making Enameled Steel Tubs, E. F. Ross, Steel, Jan. 22, p. 23.

Testing and Investigating

Planning and Evaluating Physical Tests on Steel Parts, E. F. Lake, Heat Treating & Forging, Jan., p. 22. . . . . Control of Notched Bar Impact Test, Max Moser, (Paper for American Society of Mechanical Engineers). . . . . Minimum Dimensions of Test Samples for Brinell and Diamond Pyramid Hardness Tests, G. A. Hankins, Journal of the Institute of Metals, Dec., p. 216. . . . . Hardness Testing, E. E. Halls, Machinery, (British) Dec. 28, p. 375.

Mathematical Analysis of Stress Concentration Around Inclusions and Flaws, J. N. Goodier, Paper for American Society of Mechanical Engineers.

Interpretation of Photomicrographs, J. W. Jones, Iron & Steel Industry, Dec., p. 87.

Use of X-Rays for Testing German Railway Materials and Equipment, Welding Industry, Dec., p. 337.

Constitution of the Alloys of Iron and Manganese, M. L. V. Gayler, (Paper for Iron & Steel Institute Meeting) Abstract in Nature, Jan. 20, p. 111. . . . . Diffusion on Iron-Silicon Alloys During Heating, N. A. Ziegler, Technical Paper 538, A.I.M.M.E. . . . Transformations in Pure Iron, R. F. Mehl, Technical Paper 521, A.I.M.M.E. . . . . Structure of Iron Alloyed with Nitrogen or Phosphorus, R. F. Mehl, Technical Paper 539, A.I.M.M.E. . . . . Low Temperature Martensite, O. A. Knight, Technical Paper 537, A.I.M.M.E.

Scientific Research in Non-Ferrous Metal Industries, C. G. Fink, Engineering & Mining Journal, Jan. p. 31.

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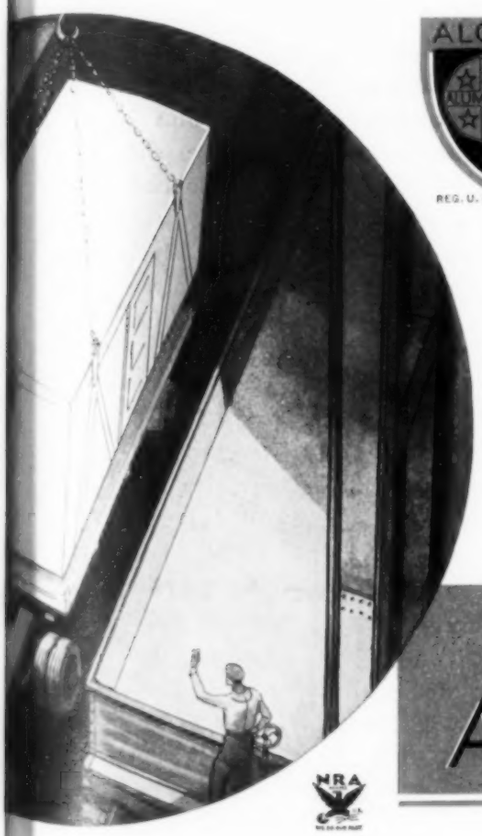

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Induction Melting

(Cont. from page 19) range for the individual elements is presented in the table for 5% chromium steel, which speaks for itself.

Ten Heats of 5% Cr, 0.5% Mo Steel

Heat No.	C	Mn	Si	Cr	Mo
1	0.166	0.55	0.38	5.12	0.49
2	0.165	0.53	0.40	5.10	0.50
3	0.163	0.45	0.25	4.86	0.50
4	0.168	0.48	0.34	4.78	0.52
5	0.187	0.56	0.32	5.05	0.52
6	0.175	0.56	0.32	5.06	0.52
7	0.187	0.56	0.34	4.90	0.51
8	0.185	0.48	0.34	4.85	0.53
9	0.172	0.53	0.34	5.00	0.56
10	0.179	0.55	0.25	5.04	0.56
Maximum	0.187	0.56	0.40	5.12	0.56
Minimum	0.163	0.45	0.25	4.78	0.49
Spread	0.024	0.11	0.15	0.34	0.07

In view of the fact that induction furnaces require a comparatively short melting period, it is not feasible to take samples prior to tapping for check analysis. Induction melting, therefore, requires that the analysis of the charge be known exactly. Careful handling and sorting of scrap for the storage bins is essential. Very little trouble has been experienced on this score at the plant of the Babcock & Wilcox Co. in spite of the fact that we regularly produce some 30 different alloy steels and a much larger number of special analyses of heat and corrosion resisting alloys, both as castings and as forging ingots.

The possibilities of controlling the gaseous atmospheres offered by the induction furnace melting are of special interest to the metallurgist. Both melting and casting under vacuum are being widely used in laboratory studies of gas-free metals, and one large industrial installation of this kind is in successful operation in Germany. Several heats of corrosion resisting alloys have been made by the writers under different types of gaseous atmospheres and it is expected that further work will be conducted on melting under vacuum and under controlled atmospheres as information on the effect of gases in metals becomes more complete.